Petroleum
NOVEMBER 1960
REFINER
FOR THE HYDROCARBON PROCESSING INDUSTRY

PETROCHEMICAL DEVELOPMENTS ISSUE

POLYOLEFINS TODAY

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pumping power to fit the need!

U.S. HOLLOSHAFT, MEDIUM THRUST MOTORS

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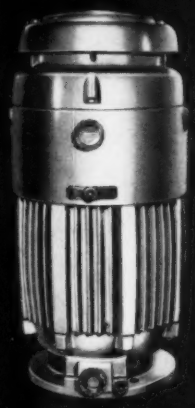

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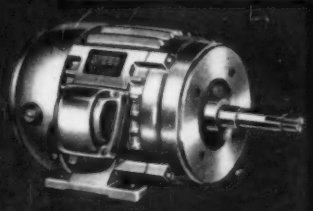

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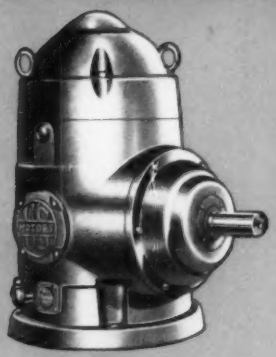

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PETROLEUM REFINER published on the 12th day of each month. Second class postage paid at Houston, Texas.
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Petroleum
REFINER
FOR THE HYDROCARBON PROCESSING INDUSTRY
A Gulf Publishing Company Publication

A Quick Look

at this issue

These handy digests permit checking ☑ the articles you want to read first.

PETROCHEMICAL DEVELOPMENTS

☐ **Polyolefin Processes Today . . .** This timely article offers you an extensive review of the state of the art in these important processes. You can get up to date fast by turning to **Page 162.**

☐ **Which Acetylene Feed is Best? . . .** This article compares the effect of methane, ethane and propane on overall manufacturing costs. The effect of fuel, oxygen, and investment costs for various paraffin feeds are thoroughly discussed. For some red hot data for your design book, turn to **Page 223.**

☐ **Which Isoprene Route is Best? . . .** Here are valuable outlines of different starting materials for your study. Add this top-notch data on another important monomer to your files. Simply turn to **Page 227.**

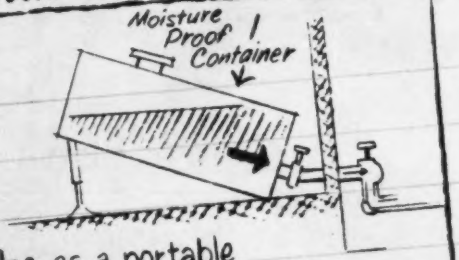
☐ **New Process for Pure Isoamylenes . . .** For a first-class description of a new alkylation method for C_5's which gives a product of almost 99-percent purity, you'll want to read this excellent article. For complete details, turn to **Page 229.**

☐ **Applied Hydrocarbon Thermodynamics . . .** Part 23. Here are several interesting methods for evaluation of the vapor fugacity and activity coefficients for mixtures. Clear graphical and analytical methods are presented for your benefit. See **Page 233.**

☐ **How To Specify Agitators . . .** Specifications for agitators are often ambiguous and require assumptions and interpretations, on the part of the vendors, that may vary widely. By writing a good specification,

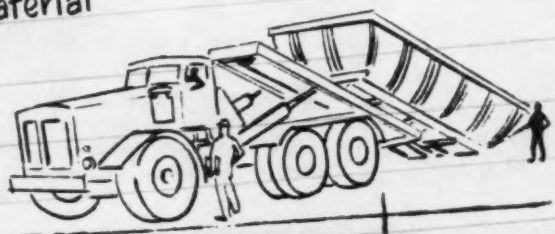
Please Turn Page ➔

Materials Handling Ideas with the Dempster Dinosaur



Use as a portable Hopper for temporary storage of wet or dry material

Use as a portable cable reel station - or for handling rolls of paper or steel



Shift heavy in-plant movements from rails to rubber with Dinosaur and 100,000 lb. capacity trucks... For slag... ingots... stone or chemicals.

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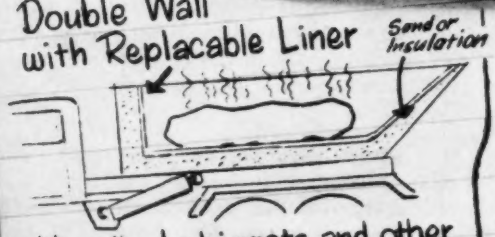
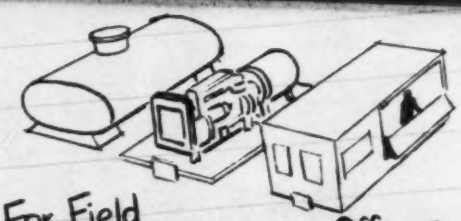


Handle hot ingots and other materials with insulated containers.



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A Quick Look at This Issue . . .

a 10-percent saving in first cost is probable. Further savings in installed costs, performance and maintenance resulting from a good specification could easily double that figure. To see how you should write your next agitator specification, turn to **Page 243.**

☐ **Automation Today . . .** Part 23. Here are two relatively simple examples of nonlinear control systems. They illustrate, clearly and quickly, how you can handle this type of control problem. For all the details, just turn to **Page 247.**

☐ **Ferrofining—New Process Lube Oils . . .** This Hydrotreating process has a rugged catalyst that treats straight-distillate lubricants which normally receive acid and clay treatment, as well as solvent-refined oils. An operating cost of 19.7 cents per barrel is far less than the cost of a conventional finishing process. For some valuable and timely information on Ferrofining, turn to **Page 251.**

☐ **How Pressure Affects Gravity of Oils . . .** This nomograph permits convenient estimation of the specific gravity, at 60° F, of oils over wide ranges of temperature and pressure. Clip this one for a handy reference. Turn now to **Page 254.**

☐ **New Tests for Carburetor Icing . . .** Simple engine tests have just been developed to show icing tendencies of gasoline. Additive requirements can be predicted from these tests or from physical properties of the gasoline. Check this new study on **Page 255.**

☐ **How to Select Demineralization Systems . . .** Here's capital investment and operating cost, as a function of raw water quality and ion exchange system arrangement. It will help you select the best water treatment system for your needs. To evaluate your present and future systems, be sure to see **Page 261.**

☐ **Why Problem-Solving Between Groups Sometimes Fails . . .** Applied Group Dynamics: Part 7 . . . What are the real reasons labor-management negotiations sometimes break down? Why can't two groups within a company agree on an issue? You will learn the answer to these and other questions on group dynamics in this article, which you will want to clip and add to the others in the series. Turn now to **Page 269.**

☐ **Short Course on Labor Law . . .** Have you ever wondered how the Federal government got into the labor relations picture, and which parts of our Constitution are used to jusify Federal labor legislation? If so, this interesting and informative article will answer your questions, as well as offer a three-minute quiz to test your present knowledge of labor law. Turn to **Page 274.**

From New York to Delhi . . .

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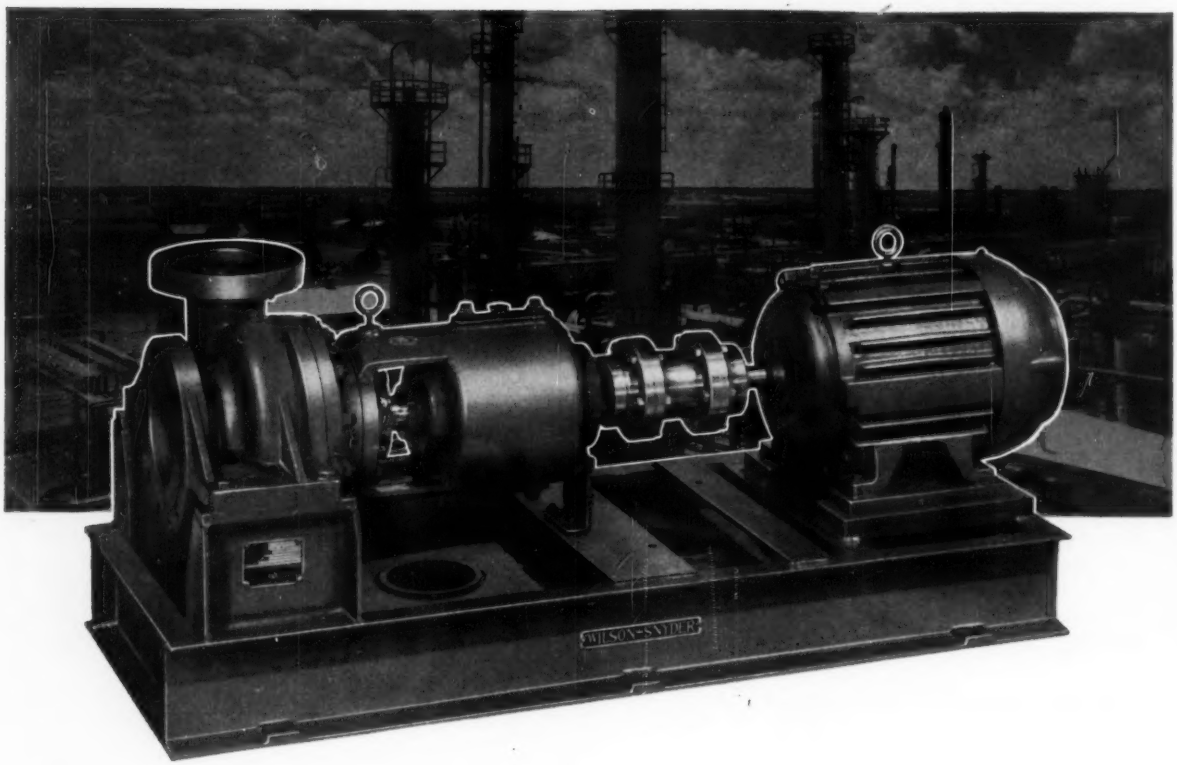
You Will Want . . .

Marshall Sittig's fine report, "Polyolefin Resin Process" found on Page 162 of this issue is to be expanded and printed in hard-back book form. In addition to the information contained in this Report. the book will be completely indexed and will list all U.S. polyolefin patents in order of application. This listing will contain patent application serial number, date, U.S. patent number and book reference number. This book will be available for purchase in March, 1961, from Gulf Publishing Company's Book Division. You can reserve your copy now by circling number E-37 on the Reader Service Card in the back of this issue and mailing.

Other new Gulf Publishing Company books of interest include:

Operator's Handbook. All 12 parts of this popular series devoted to gasoline plant problems is to be published in hard-back book form shortly after the first of the year. You can place your order now by circling number E-38 on the Reader Service Card.

Estimator's General Construction Manhour Manual, by John S. Page. The third in Gulf Publishing's Estimator's Manhour Library, this book provides scores of manhour tables containing thousands of listings which are valuable guides to estimating manhours in every phase of general construction work . . . in any location. Priced at $10.00 a copy you can order by circling number E-39 on the Reader Service Card.



Wilson-Snyder announces a new line of heavy-duty Centrifugal Process Pumps—Type ESN

for maximum efficiency, dependability and economy

This all-new Wilson-Snyder Type ESN pump meets all and exceeds many of the requirements of A.P.I. Specifications and incorporates the following outstanding features:

- Double volute case design, for maximum radial balance at all load conditions in all sizes starting with 3″ discharge and larger.
- Superior shaft design, with double row radial and double row angular contact type thrust bearings.
- Impeller designed for lowest possible NPSH without sacrifice of efficiency.
- Large effective cooling passages integral with stuffing box and bearing housing are designed for temperature applications up to 900 degrees F.

High-strength shaft design combined with double volute case design reduces shaft deflection to absolute minimum and allows widest possible range of operation. The double row ball radial and thrust bearings have been selected to assure long-life performance and lowest maintenance cost. Ring-oiled bearing lubrication with a large built-in oil reservoir provides positive and ample lubrication to all bearings. Stuffing boxes are designed for maximum packing standardization and all standard makes of mechanical seals can be applied interchangeably.

ESN pumps are available in a complete range of sizes, both single and 2-stage—end suction standard, top suction optional, on all single-stage pumps. Only five bearing bracket assemblies cover the complete line for horsepower applications up to 350. ESN pumps can be furnished in a wide range of metallurgy, including alloys suitable for highly corrosive and abrasive liquids.

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PETROLEUM REFINER
Is Published By
GULF PUBLISHING COMPANY

EXECUTIVE OFFICES: 3301 BUFFALO DRIVE, HOUSTON
Cable Address, Gulfpubco, Houston
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SUBSCRIPTIONS
R. B. Reilly, Circulation Manager, P. O. Box 2608, Houston 1, Texas U.S.A. Single copies 50 cents (except special issues) for domestic and foreign. Double price for copies over one year old. Subscription rates—both foreign and domestic $2 a year. Subscriptions restricted to those engaged in the hydrocarbon processing industry, or service and supply company personnel connected thereto. Copyright 1960 by Gulf Publishing Company.

Postmaster: Send notification (Form 3579) regarding undeliverable magazine to Petroleum Refiner, Box 2608, Houston 1, Texas.

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PIPE LINE INDUSTRY and The PIPE LINE CATALOG for the oil and gas pipe line industry.

Petroleum Refiner is indexed by Industrial Arts Index, Chemical Abstracts and by Engineering Index, Inc. Microfilm copies available through University Microfilms, Ann Arbor, Michigan.

To Ranch for Study

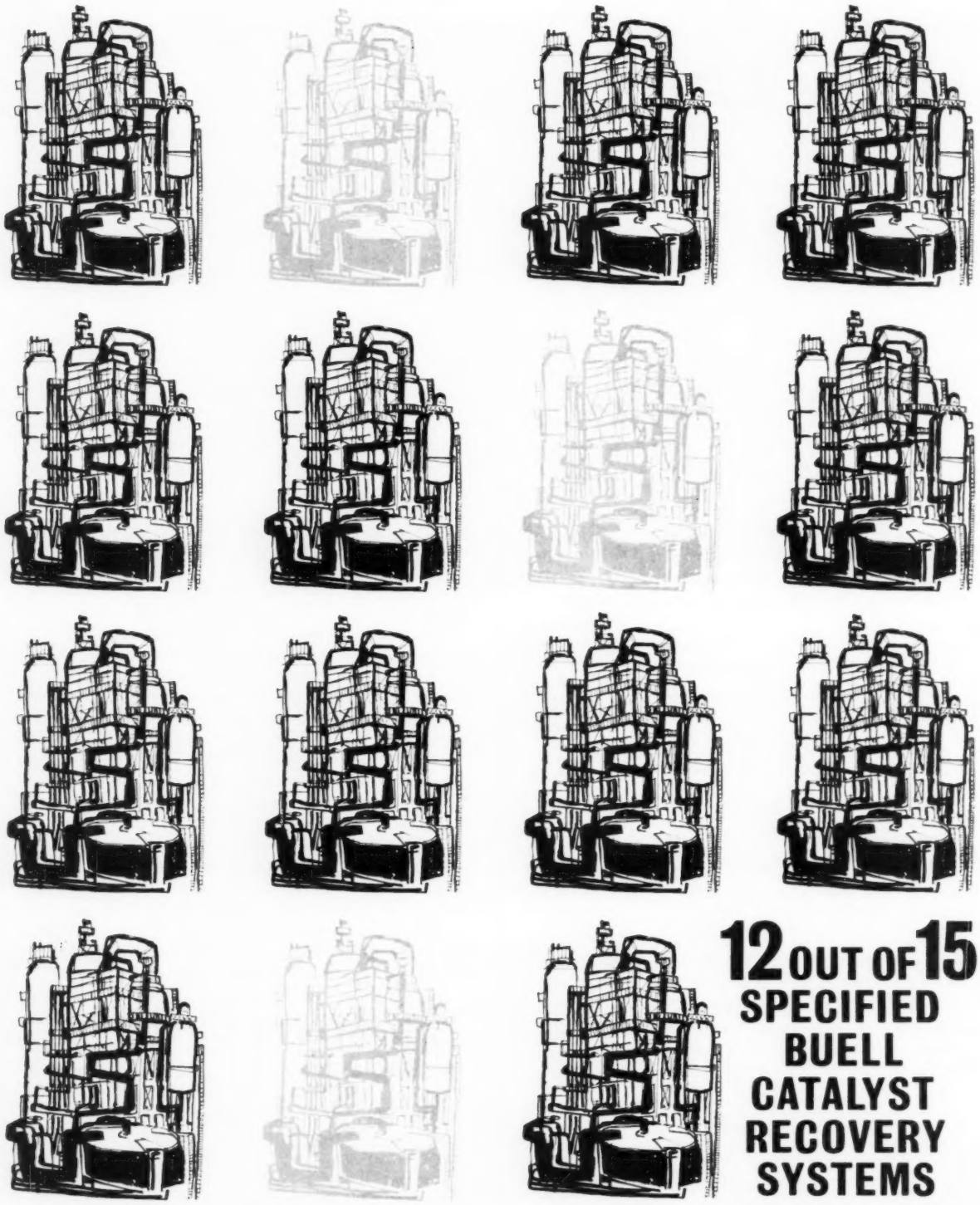
SOME 25 MEN will gather early in December at old Fort Clark, near Brackettville, Texas, and will spend the better part of a week studying problems —mostly editorial—incident to publication of PETROLEUM REFINER. Staff members will be there, of course, and in addition there will be five high-ranking men from the HPI field who will serve as advisors to the assembled editors. These men hail from Lake Charles, La., Kansas City, Mo., Bartlesville Okla., Baytown and Houston and will bring to the conference the "outside" viewpoint while at the same time making suggestions and criticism along technological lines. This procedure, looking toward better coverage of HPI developments, has been a definite factor in improved and better rounded service to our readers. Such service is PR's constant aim and these annual conferences with industry guests, held virtually every year since right after World War II ended, have had a big part in helping us to attain that goal.

Real "How" Report

OUR DECEMBER ISSUE, which claims the track now that the November issue has arrived at its destination, has, like our "As Management Sees It" section a wide reader appeal. Its Special Report: "Technical Communications," a subject that is dear to the hearts of engineering management and any of our readers who have to make written or oral reports to the boss. And that, of course, is most of them! The technical man will find this issue quite valuable because he can be successful in his field only if he is able to communicate his ideas to others. The several carefully selected articles booked for our December issue will teach the reader HOW to communicate and should serve him as a textbook for years to come. It's a real up-to-snuff "package deal" on communications—about everything one needs to know on the subject in the single issue. So keep it in mind for your own benefit and if any of your chums need counsel in this general area, tell them about it too.

The Warm Circle

RUNNING INTO tried and true friends of PETROLEUM REFINER—men who read and have been reading the periodical for years and who "swear by it" is the pleasant experience Gulf Publishing Co. people report with frequency. Our foreign representatives, for example, never cease to thrill at the treatment accorded them by business and technical men when they learn that they represent PR. And our editorial staff people in their travels both at home and abroad have had like experiences. Only last month one editor sat next to two young chemical engineers. Upon introductions, one revealed that he was an ardent PR fan, had even sold six subscriptions to his colleagues. And his friend sitting next to him confirmed the claim immediately because he was one of the six. Thus our circle grows, and are we proud!



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Quick Look at Industry...

Quick Look Around the World . . .

Mobil marketing new petroleum additive claimed to give better anti-knock quality than any other in use, with boiling point of 230°F . . . IPAA again calls for lower import allowables to "maintain proper balance between imports and domestic production" . . . Bureau of Mines foresees 1960 U.S. motor-fuel consumption increase of 3.5% over 1959 . . . West Germany's fuel oil consumption in first half jumps 39.6% over like 1959 period.

Italy agrees to buy 12 million tons of Soviet oil over four-year period . . . OCAW beats out independent union in election for representation rights at Mobil's Buffalo, N.Y., refinery . . . Sinclair shuts down three main processing units at Corpus Christi, Texas because "units couldn't be operated efficiently any longer or economically maintained."

Sizing Up Supply and Demand . . .

November domestic crude demand forecast at 6,925,000 bpd by Bureau of Mines. Included in estimate: Gasoline demand, 4,110,000 bpd; gasoline yield, 45.5%; total crude runs, 7,910,000 bpd. Bureau looks for little increase in third-quarter demand for crude and products, compared with like 1959 period.

Smog Warnings East of Rockies . . .

Advance warning of severe smog conditions now available to all cities east of Rocky Mountains via teletype from Weather Bureau station at Sanitary Engineering Center, Cincinnati. "Stagnation Bulletins" will help danger areas curb smog sources during critical "calm air" periods. Reports will go to local weather stations—then to air pollution officials and industry representatives.

Refinery Sails for Guatemala . . .

Prefabrication extends to refinery construction as Lummus ships 4,000-bpd plant to Guatemala. Built in United States, unit will be erected on poured foundation pads in jungle near Barrios—will produce all petroleum products except lube oil. Reason for prefab, which is world's largest such project: lack of skilled labor in Guatemala.

Scale Models Picking Up Steam . . .

Look for more use of scale models to cut engineering costs. At ASME Petroleum Division meeting in New Orleans, Foster Wheeler said it takes 50,000 manhours for mechanical design of crude distillation unit. Plant models enable them to "cut costs 25%—or down to 37,000 manhours."

Oil-Company "Price Fixing" Back in News . . .

Northern Indiana District Court begins trial of 13 oil companies under October 1958 indictment. Charge conspiracy to fix gasoline pump prices April-May 1957 to "end price war." Defendants in trial, which started November 1: Indiana Standard, Mobil, Gulf, Sun, Texaco, Ohio, Phillips, Shell, Cities Service, Tornado, Hudson, Pacer and Central West.

From U 235 to Improved Lubes . . .

Thermal diffusion process used to make U 235 during war for "A" bombs being employed in manufacture of lubricants by Standard of Ohio. Cost reductions of 40% are claimed as result of major advance in design of thermal diffusion equipment. Net result: a 10-unit, $110,000 plant should yield "between 1,200 and 3,300 gallons a day of high-viscosity oil product."

Fuel Cell Still in Spotlight . . .

Long-term research program to advance fuel-cell technology begun at Battelle Memorial Institute, Columbus, Ohio. Underwritten by 25 com-

panies, five-year program will be fundamental—designed to complement current government, industrial, and academic studies on fuel-cell technology . . . Meanwhile, Shell Research comes up with low-temperature fuel cell that generates three to five times more power per unit volume than similar cells under development.

Merging the Old and Forming the New . . .

Standard of Indiana stockholders unanimously approve corporate reorganization at special meeting . . . Three subsidiaries of Godfrey L. Cabot, Inc., merge to form Cabot Corp. The three: Cabot Carbon, Cabot Gasoline and Cabot Shops . . . Allied Chemical unites Polyethylene Manufacturing, Marketing, and Plastics Departments to form Plastics Division. Humble closes deal to buy out Monterrey Oil Co. . . . Tennessee Eastman forms Eastman Research A.G. in Switzerland. . . . California Chemical absorbs Standard of California subsidiaries California Spray Chemical and Oronite Chemical. They become Ortho and Oronite Divisions . . . Tidewater sets up Veedol International to supervise all European manufacturing and marketing subsidiaries other than Dansk Veedol.

No Trouble Ahead for Petrochemicals . . .

U.S. can maintain lead in world petrochemical markets because of high efficiency and cheap raw materials says Union Carbide Veep Howard S. Bunn. The reason: Assigning the U.S. a raw material and labor index of 1.0, note that British workers earn 1/3 U.S. rate—but labor cost index is almost 0.5. As for other countries: Brazil, index of 0.72, wages 1/5 that of U.S.; Canada, index of 1.21, wages 15 percent less than U.S. Raw materials, based on U.S. index of 1.0, show Scotland with 1.46, Brazil with 1.11, Italy with 1.32 and Canada with 1.24.

Eyeing the Automation Picture . . .

Standard of Indiana revamps computer to guide 140,000-bpd Whiting, Ind., distillation unit. This is first time computer system has so completely controlled industrial operation this complex, says company. . . . Socony Mobil sets up $3-million digital computer for New York Computer Center . . . Sinclair forms special department to coordinate data processing and computing activities of operating subsidiaries.

Sun Oil Veep Chalmer Kirkbride urges continued efforts toward automation before Congressional Committee. His reasoning: Population outstripping needed work force, shorter work week and more holidays ahead, along with huge increases in national output.

Quick Look at World-Wide Construction . . .

World's second largest MEK solvent dewaxer comes on stream at DX Sunray's Tulsa refinery at cost of $7 million. . . Tidewater and Collier Carbon & Chemical to double Delaware refinery's naphthalene production to 100 million-pounds a year . . . Union Carbon to build 64-million-pound-per-year carbon black plant in Southern California . . . BP and California Chemical plan $19.6-million aromatics project including one plant at Kent, England, another at Dinslaken, Germany . . . SunOlin to build $20-million ethylene and ethylene oxide plant at Marcus Hook, Pa. . . . More about construction beginning on page 294.

What's Ahead for Oil in Congress? . . .

Watch for trouble over oil in next Congress. The big picture: More opposition to percentage depletion, especially among legislators seeking reduction; big effort to block new renewal of reciprocal trade agreement; pressure by national-fuel-policy advocates; strong demand for additional gasoline taxes. Such are views of Archie D. Gray, Gulf Oil's senior veep.

Fences and Separation in Anti-Strike Measure . . .

Mobil Chemical casts eye toward possible future labor troubles as it completely separates new Beaumont plant from refinery there—including duplicate utility facilities and a fence around site. Reason: In case labor dispute shuts down either new unit or refinery, remaining plant will be operative.

B&W
WELDING
FITTINGS

MADE BY MEN WHO KNOW TUBING

B&W Welding Fittings manufacturing is integrated with the Division's own tube-making and steel-making facilities. Consider the relation between tube-making and the manufacture of welding fittings . . . in addition to knowing welding fittings manufacturing, B&W knows of the making of tubing from which fittings are produced. This knowledge plus integration of facilities permits B&W to provide superior fittings, completely quality-controlled, matched to end-use service. It also means on-time deliveries of fittings made from tubing of the specialized steels because B&W can closely control manufacturing schedules from melt to the shipment of the finished product.

B&W Welding Fittings and Flanges are available through qualified distributors in carbon steel and the B&W CROLOYS in a complete range of types and sizes. Write for B&W Bulletin FB502. The Babcock & Wilcox Company, Tubular Products Division, Welding Fittings Plant, P. O. Box 230, Beaver Falls, Pennsylvania.

B&W

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TUBULAR PRODUCTS DIVISION

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Seamless and welded tubular products, solid extrusions, seamless welding fittings and forged steel flanges—in carbon, alloy and stainless steels and special metals

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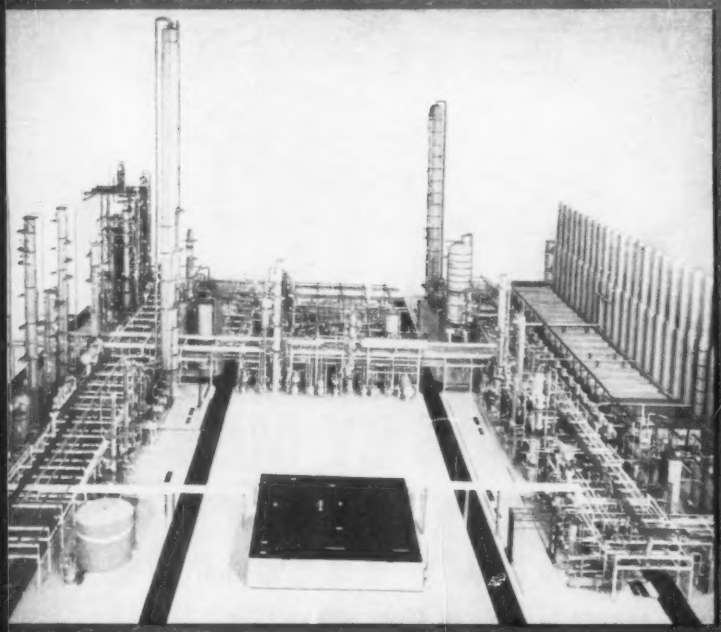
Kellogg Engineers and Builds World's Biggest Olefin Plants



Mobil

FUTURE WORLD'S LARGEST is Socony Mobil Oil Company's ethylene plant at Beaumont, Texas. It is the first large plant in the U.S. to crack naphtha into olefins. Engineered by The M. W. Kellogg Company, as shown in this scale model, it is scheduled for completion by Kellogg by 1961. Capacity will be 380 million pounds annually of 99.9% purity ethylene.

This newest plant consists of steam pyrolysis, gas treating, and product recovery sections. It has been designed to handle simultaneously both liquid and gaseous feedstocks. In addition to ethylene, major products will include propylene, propane, a B-B product, gasoline, and fuel oil.

ICI

LARGEST OUTSIDE THE U.S. is the English Wilton Works of Imperial Chemical Industries, which now includes three olefin plants. Photograph shows Plant No. 3. All are the result of close engineering cooperation between Kellogg and I.C.I. Together, they represent a current output of 110,000 tons per year of high-purity ethylene, and a potential of 140,000 tons.

Plant No. 1, commissioned in 1951, was the first full-scale adoption of the then novel process of oil pyrolysis developed in Kellogg's laboratories. Its success led to the addition of Plant No. 2 in 1956, and then to No. 3—representing a 60% increase in olefin capacity—in 1959.

Whether your approach to ethylene is through the steam pyrolysis of hydrocarbons or the recovery of ethylene from gas mixtures, Kellogg has developed processes which can assure the optimum investment, operating costs, product purity, and yield. For more information about Kellogg's 2-billion-pound background in engineering and/or building ethylene plants, write for a copy of "Olefin Plants" Kelloggram.

M KELLOGG W

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The Look Box...

Safety Attained Through People, Not Things

THE TITLE "safety engineer" is a misnomer and should be changed to better fit the safety man's job—and his job should be changed to better fit his company's needs. This universal problem was well crystallized at last month's National Safety Council convention in Chicago, attended by one of PETROLEUM REFINER's editors. In a talk entitled "What's Wrong With the Safety Engineer," nationally known safety consultant Alfred Lateiner pointed out that the prevention of work injuries is largely a personal problem rather than an engineering problem.

Said Mr. Lateiner, "safety has to be obtained through people rather than things. Accidental injuries are usually 80 percent man failure versus 20 percent machine failure. Therefore, we must improve the knowledge, willingness and abilities of the work force. This calls for a teacher, executive administrator, communicator—not an engineer." A suggested title for the safety man: accident control coordinator.

A real problem area for the safety coordinator, says Lateiner, is one of staying strictly within the bounds of administrative and supervisory work, rather than degenerating into a clean-up man or police-job specialist. The safety man's job is to motivate *others* to work safely—not to perform the safety function himself. This ability to inspire people to good habits and practices distinguishes the professional safety specialist from the amateur.

Witness the advice of expert Lateiner on ways that safety personnel can improve their lot *and* the company's accident record. "We often try to be technical experts in the 1,000 areas of work technology that confront us in our modern complex organizations. We should use for advice the chemist, engineer, electrician, physicist and other highly competent personnel in our own companies.

We may also call for help on technical problems by using the National Safety Council, U.S. Department of Labor, outside suppliers of equipment and materials, consultants, and various government agencies.

Our accident control coordinator should (1) see that personal protective equipment is always available, (2) that adequate individual investigation and reporting is maintained, (3) feed back monthly analyses and measurements, (4) organize and work with safety committees, (5) set up and maintain a systematic inspection and recommendation procedure, (6) keep superiors informed, and (7) stimulate interest, enthusiasm and activity in a going comprehensive safety program.

He should take care not to become a fanatic with one-sided tubular vision—who can see only one way to achieve safety. There is the "goggle" type, the "safety shoe" bug, the "contest happy" fanatic, the "sell the boss" character, the "revivalist-meeting preacher" type, etc.

He must round out his approaches—but beware of the well-rounded "hollow" type. The core of a good *basic* program must be there for real success."

Taking for Granted Has Two Sides

THE OIL INDUSTRY'S biggest customer is—you guessed it—our much discussed and sometimes cussed Uncle Sam. All other customers play second fiddle.

For, as pointed out quite graphically in The Ohio Oil Company's employe magazine "The Beacon," "in a year when their demand has declined slightly, the oil industry's biggest customer—the U.S. Military—will buy close to 700,000 barrels of petroleum products a day." (Actually, the figure for the second quarter this year averaged 748,000 barrels daily.) And that, we are reminded, is more than the entire expected daily output of the state of Oklahoma.

Oil's role thus only in a relative sense has been reduced since the World War II days when victory came to the Allies because we had the oil and the enemy did not. Oil continues to take the lead in maintaining strength that our defense experts think is essential. And who can deny their contention when rumblings and threats are heard every day, many times in halls whose very foundations is peace itself?

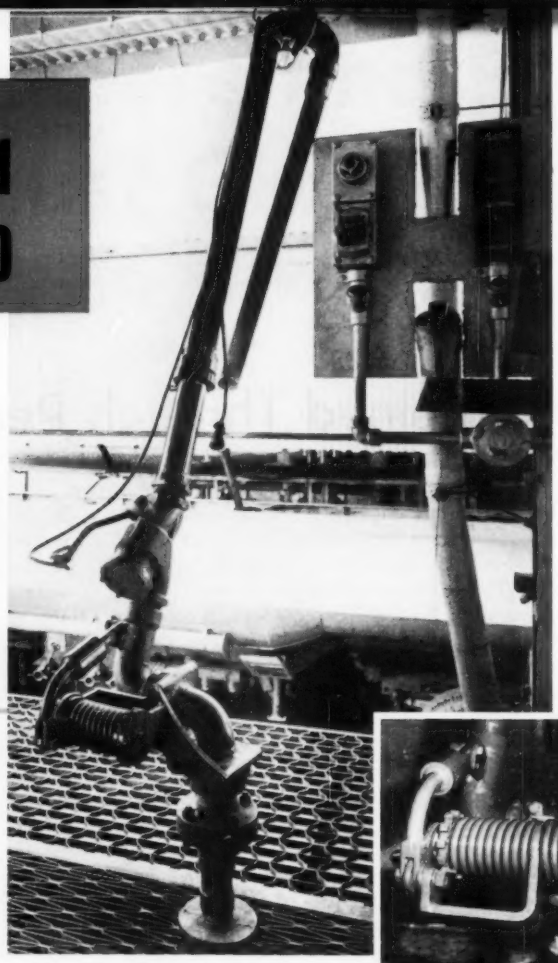
It is, of course, a billion dollar per year deal, this purchase by U.S. defense forces of the products which our industry turns out. Jet fuel right now is the big item, but the demand continues for gasoline and diesel fuel as well as other distillates and residuals. Navy special fuel oil has been an especially big item this year. Thousands upon thousands of barrels daily of these items are bought by the Military Petroleum Supply Agency. Truly the demand and, of course, the facilities to supply the demand are gigantic.

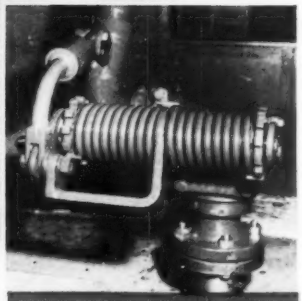
The oil industry more or less takes it for granted that this good customer will always be in line. Won-

IT'S *NEW* FROM CONTINENTAL-EMSCO

SPRING-BALANCED *LOADING ARM*

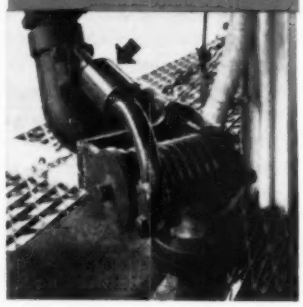
. . for faster, safer loading of petroleum and chemical products





DOUBLE SPRING ASSEMBLIES are available on standard units to balance heavier loads.

EXCLUSIVE SNUBBER SPRING . . enclosed in the housing above main spring . . . absorbs arm's upward thrust.



You can see how Continental-Emsco's use of a torsion-type spring makes this loading arm compact and streamlined. Weights, pulleys, cables are eliminated, so platforms are cleaner . . more modern looking . . safer for personnel.

These thoroughly field proven, extremely rugged units incorporate heavy-duty bearings which are widely spaced to withstand continual loading and sudden, severe shocks. Riser joints are made of steel to take the punishment of the hardest loading operations. Packing can be replaced without removing joint from the arm or disturbing bearings, and Buna "N", Teflon or Viton "A" packing is available for handling a wide variety of products . . assuring the lowest possible cost.

Standard models are available in 3″ or 4″ sizes in either rigid or telescoping designs with flanged or threaded riser connections. Six standard models provide the variety of designs necessary to replace old arms or to equip new platforms at minimum cost. Custom-designed arms can be furnished to fit any special installation. Modernize your platform with competitively priced Continental-Emsco spring-balanced loading arms.

Write, wire or call today for complete information.

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SJ006

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der if Uncle Sam, likewise, ever gives thought to the picklement the nation would be in if the oil industry hadn't, through research and technological development, kept pace with the times so that these essential products would be available as and when needed?

Individual Output Must Rise

NEWS ITEMS TELL US that the OCAW is eyeing the Gulf Coast again for union activity looking toward new contracts—with increased wages, of course—backed by possible strike action. So refining companies, it would appear, face a continuously interesting period.

The effect of automation in HPI plants doubtless will be, as it has been in the recent past, one of the questions introduced at the bargaining table. Forces of men laid off for any reason is never a very pretty picture.

In this connection the testimony of Dr. Chalmer G. Kirkbride, Sun Oil Co. vice president, before a congressional committee studying progress and problems of automation is most interesting. "Automation represents the type of technological progress we must make if we hope to maintain or improve our standard of living," is the way he put it.

"From the best estimates, there will be a greater proportionate increase in our population than there will be in the available work force," a summary of Dr. Kirkbride's views discloses.

"Taking into account that the trend toward a shorter work week, longer vacations, and additional holidays, it has been estimated that during the next 15 years the total hours worked per year by our entire labor force may not increase at all.

". . . While projections of national output in the next five to 15 years vary over a broad range . . . there can be no doubt that individual productivity must be increased.

"Clearly, the means to meet the tremendous challenge this offers lies in the proper application of automation for the ultimate benefit of our entire nation."

Straight, sound thinking, we'd say. And hard to contradict.

Not a Second Rater

THESE DAYS we hear a lot about how we are falling behind the U.S.S.R. in some fields. Some politicians would have us believe we'll soon be second raters if corrective measures aren't taken. On the oil scene, for example, has been the recent threat of Russia glutting the world market with cut-rate oil.

But, one of the first things a truly objective person will admit is that *all things are relative.* Sociologically, for example, what is good and pure in one society is evil in another. Scientifically, where one set of formulae fit a problem to a "T"—they are completely inadequate in another area or field. Psychologically, one personality will flourish in a given environment where another personality withers. And so it goes—this system of checks and balances.

With this in mind, perhaps what we forget is that in the oil industry too *all things are relative.* In the first place, a broad comparison cannot be made of the U.S. and Russian oil industries because the two are completely different—different in technology, different in product quality, different in economic structure. But on one thing American experts seem to agree—for the most part the U.S.S.R. lags far behind the U.S. in petroleum technology.

W. W. Keeler, executive vice president of Phillips Petroleum Co., who headed an eight-man delegation of American petroleum experts that recently toured Russian oilfields and refineries, said, "In the United States much of our effort is directed toward obtaining the greatest possible yield of high-quality gasoline from a barrel of crude oil. But in Russia there are relatively few passenger cars. Gasoline is considered secondary to what they really need—diesel oil and industrial fuel oil to run their machinery."

The Russians do not have some of the advanced processes and techniques the United States has, Keeler said, but the U.S.S.R. does not need them at present. "So a comparison is not valid because we are going in different directions," he added.

George T. Piercy, head of Standard Oil Co. (New Jersey) Petroleum Economics Department, another member of the delegation, said there is some indication Russia will exceed the goal of 4.8 million bpd of oil production set for 1965. By comparison, the United States presently consumes about 10 million bpd, of which 7 million are produced domestically. And this is with a curtailed production.

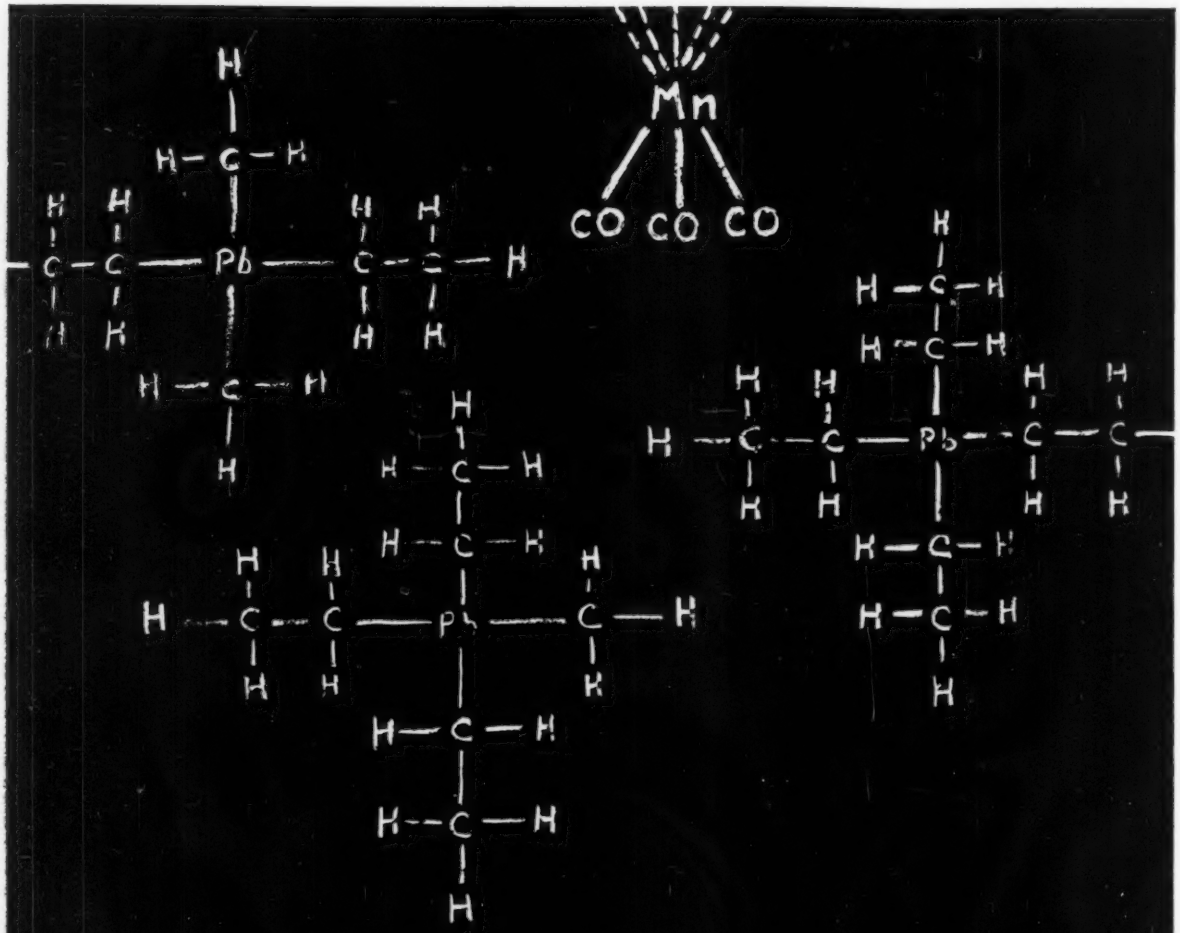
Another delegation member, Ira H. Cram, senior vice president of Continental Oil Co., said Russia can achieve her production goal with relative ease because she has huge reserves untapped—many near the surface.

All three men were impressed with the capability of Russian technicians and drilling techniques. But one thing seems certain. At present we are well ahead of the Soviet Union. And, with hard work and careful planning we'll stay there.

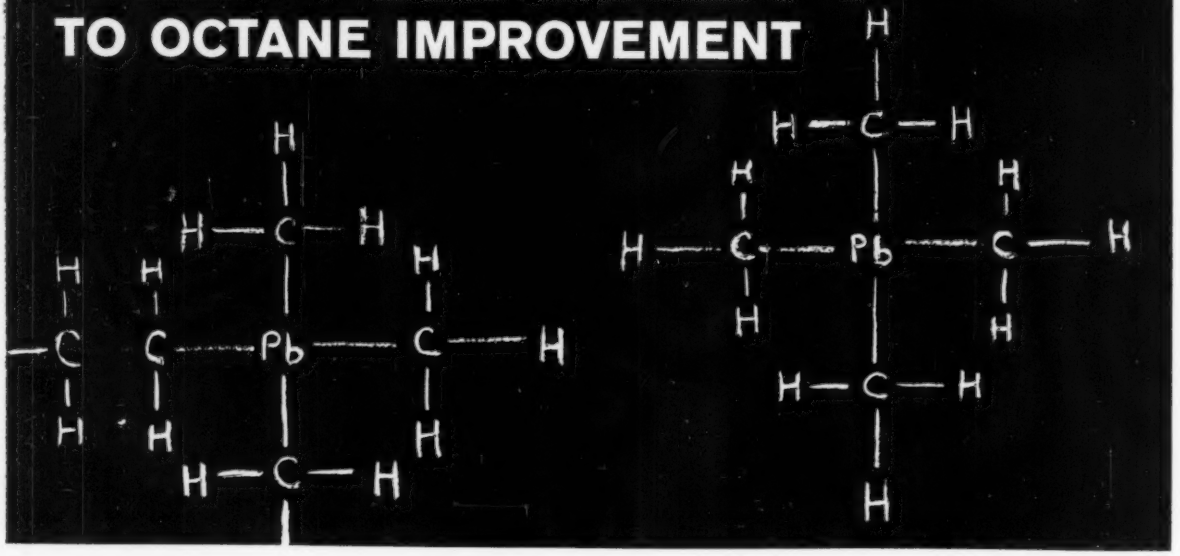
The United States must carefully scrutinize its own energy supply to insure that our own lusty economy is maintaining miximum productivity by the use of the most efficient, convenient and economic energy source.

Freedom of choice of energy source has been the key to our own economic success, and holds the same opportunity for those nations who are now beginning their modern, productive lives.

George F. Getty II, President
Tidewater Oil Company



ANTIKNOCKS ADD A NEW FLEXIBILITY TO OCTANE IMPROVEMENT



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RECENT DEVELOPMENTS in antiknock compounds have opened new areas for the refiner to consider. Just as raising the allowable limit of TEL concentration provided more latitude, new antiknocks are now available which permit even greater flexibility.

Bonus from TEL

One of the most important developments in the use of TEL came about during 1959—extending the limit to 4 ml per gallon. As a result, the average premium gasoline refined today can be increased from current levels by one and a half Research octane numbers through TEL alone. Similarly the Motor octane number gain is almost two numbers greater. Furthermore, the Road octane gain from TEL is greater than is indicated by either of the laboratory methods.

In the case of regular gasoline, almost two octane numbers can be gained through increasing TEL from present average concentration to 3 ml. The 4th ml of TEL makes possible additional octane improvement.

Tetramethyllead

Research on tetramethyllead—first of a new group of lead alkyls to be offered commercially—shows that in highly aromatic gasolines or in engines prone to induce fuel segregation in the manifold, TML can be considerably more effective than TEL in its road performance.

Mixed Lead Alkyls

Now three more "Ethyl" antiknock compounds are available: MLA 250, MLA 500 and MLA 750—all produced from mixtures of TML and TEL processed to equilibrium composition. Current tests show that these mixed lead alkyls are selective in their ability to provide superior road performance, dependent upon such factors as fuel composition.

Custom Blends

You may find that a physical mixture of TEL and TML in some special ratio is most effective for your needs. Such "custom blends" are available.

Motor 33 Mix

Another compound, Motor 33 Mix—a manganese-lead antiknock—can supply several additional octane numbers when used in certain fuels.

The Future

With this variety of antiknock compounds, each with its particular value and application, maximum flexibility is offered to the refiner. Not only do the antiknocks offer cost savings and delay capital expenditures, but they can provide benefits that cannot be obtained any other way.

REMINDERS TO REFINERS

Antiknocks are your best octane improvement buy, whether costs are figured on Research, Motor or Road ratings.

Antiknocks give you a Road octane bonus you can't get any other way.

Gasoline sensitivity can be decreased with antiknocks.

Refining flexibility can be increased with antiknocks.

Antiknocks also can reduce or delay capital investment in octane improvement equipment.

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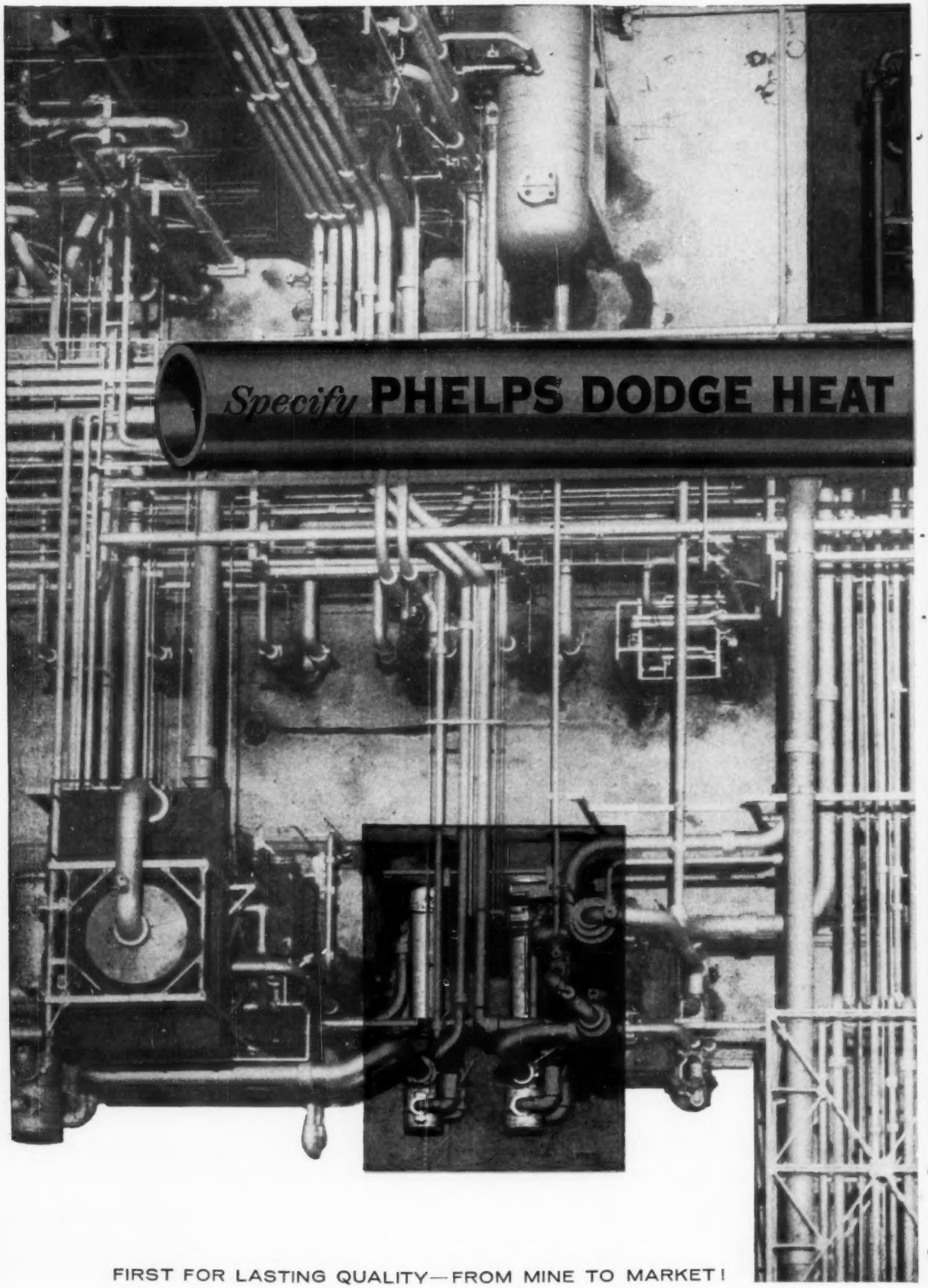

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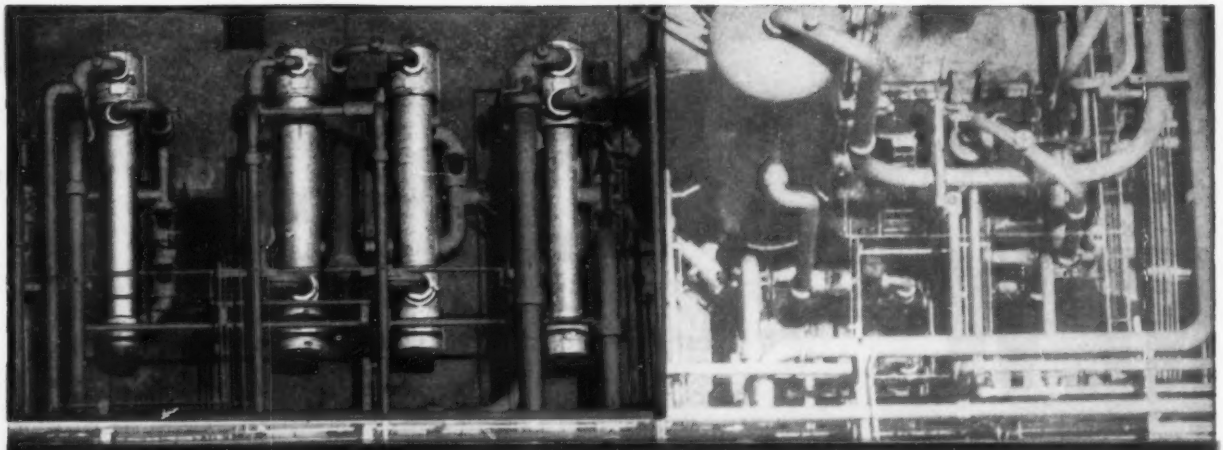

EXCHANGER TUBES *for Longer Service!*

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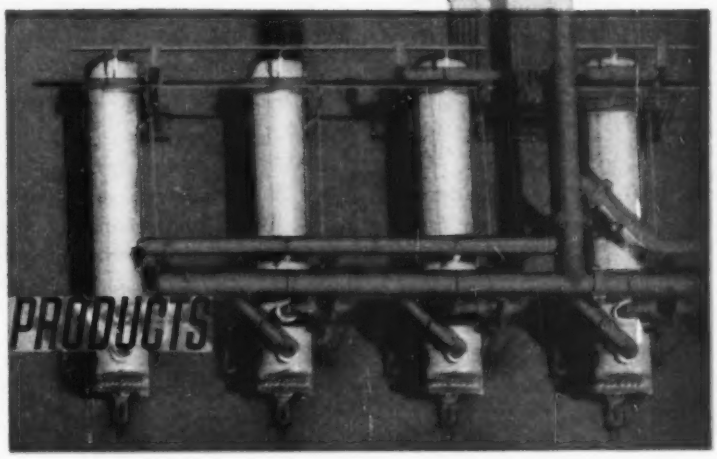

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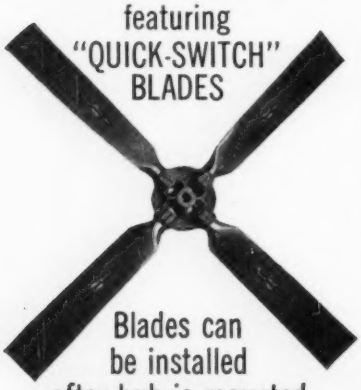

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INDUSTRY IQ QUIZ

Test your industrial IQ with this quiz on the current issue of PETROLEUM REFINER

1. How many producers of polyethylene are there in the United States today: 10, 15, 21?

2. How would you rate these three major polyethylene producers in order of annual production: Union Carbide, U.S. Industrial Chemicals, Du Pont?

3. Which of these plastic materials has the lower specific gravity: conventional poleythylene or isotactic polypropylene.

4. After an ICI chemist discovered polyethylene in 1933, how many years passed before one ton of the material had been produced: 1 year, 2 years, or 5 years?

5. U.S. production capacity for all types of polyethylene resins is estimated to reach how many pounds by 1961: 1 billion, 1¾ billion, or 2 billion?

6. When cracking heavier feedstocks for acetylene, there is less hydrogen made. True or False?

7. For the production of cis-isoprene rubber, commercial-grade isoprene is satisfactory. True or False?

8. What major new use for isoamylenes is responsible for the sudden interest in their recovery?

9. Process control systems seldom need nonlinear control. Therefore, control problems can be handled by the theories for linear systems. True or False?

10. When treating raw water with total dissolved solids of 200 ppm (as $CaCO_3$) using a duplex, cation-weak base anion system, what will the treated water cost per 1,000 gallons?

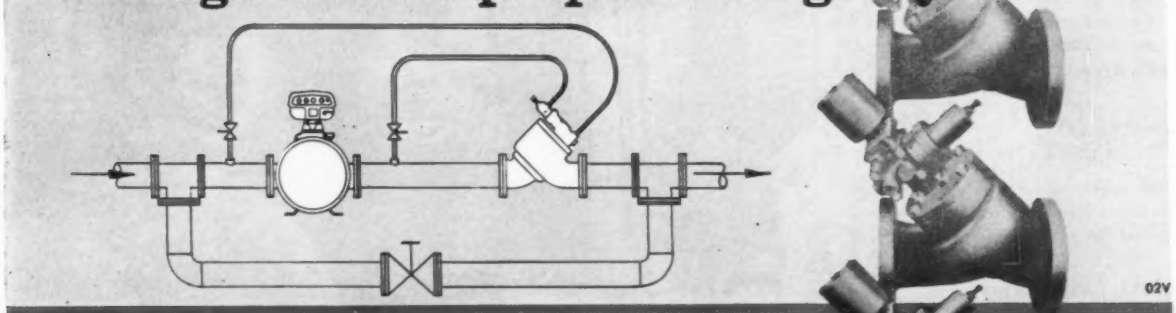
(a) 38 cents
(b) 30 cents
(c) 21 cents

11. What is one of the key reasons, in terms of group dynamics, that labor-management relations break down?

Answers on Page 398

COMPLETE ADAPTABILITY...
BRODIE Series 500 Control Valves

ONE VALVE
DOES MANY JOBS
with single or multiple pilots integrally mounted



02V

The great interchangeable versatility of Brodie Series 500 Control valves makes them readily adaptable to almost any application you can name. By simply changing or adding pilot controls the valve is ready for service. Their fully self-contained, simple, compact internal porting of integral pilots avoids hazards of fragile external "plumbing." For positive responsive control with minimal pulsations look into Brodie Series 500 Valves. **Write, today for Bulletin 668.**

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QUALITY CONTROL

Quality control influences every G.E. operation, from order receipt to shipment.

PRODUCT INNOVATION

Product research and development is advanced in all 98 G.E. laboratories.

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Customer-oriented application engineers assist you with systems integration.

ANALYTICAL ENGINEERING

The latest tools of process analysis are available for studies of your problems.

INSTALLATION AND SERVICE ENGINEERING

Expert on-site assistance gives you smoother installation and earlier start-up.

SYSTEM CO-ORDINATION

G.E.'s systems experience focuses the full Company capabilities on your order.

NATION-WIDE SERVICE SHOPS

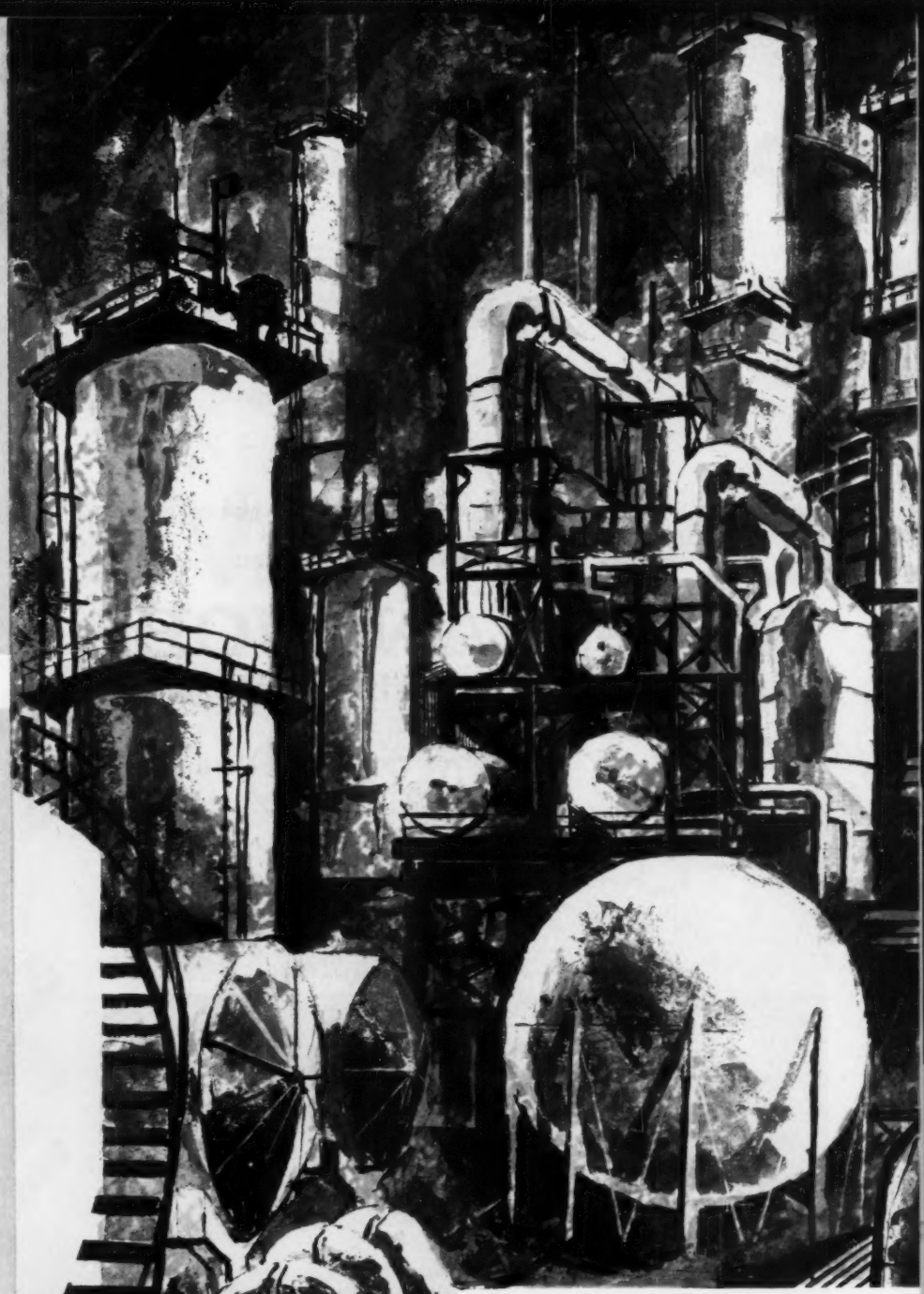
More than 50 G.E. Service Shops offer you 'round-the-clock maintenance service.

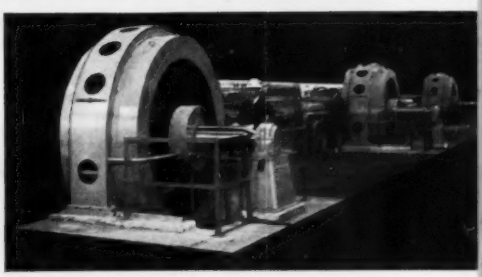
PROMPT DELIVERY

Accurate delivery cycles put your new G.E. equipment to work for you—on time.

VALUE ANALYSIS

Value Analysis gives you optimum combination of product value and economy.





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Today's cost squeeze in the petroleum and chemical process industries can be minimized when the experience and know-how of General Electric system planners is used in selecting your key process drives. G-E system planners will analyze your processes and help you design systems in which equipment capabilities are efficiently and economically matched to your particular process requirements. By taking advantage of G-E engineering assistance during the earliest planning of your new processes, you will be able to give well-defined systems guidance to your engineering contractor or consultant.

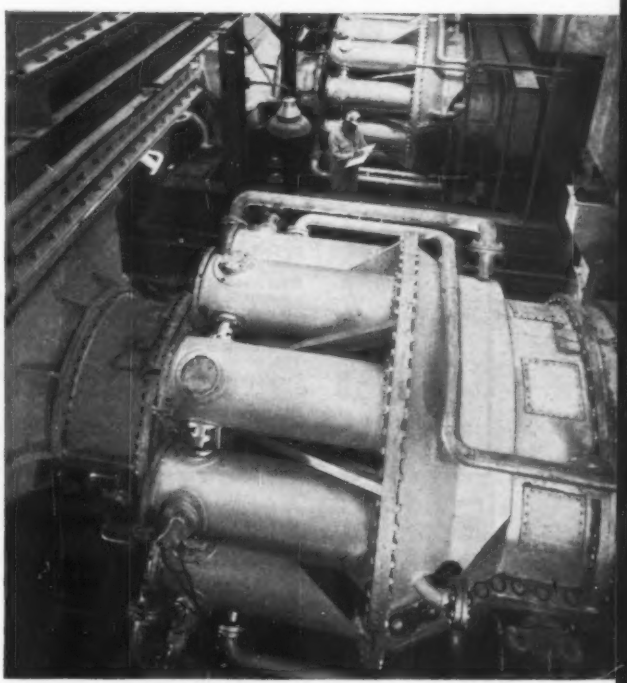
FOR EXAMPLE, GENERAL ELECTRIC SYSTEM PLANNERS recently recommended three gas turbines to drive key compressors and blowers at a new ethylene process plant. These three 13000 hp G-E turbines are not only providing reliable shaft power but also a power bonus by economically supplying hot gas for heating process air and making steam. Designing such flexible, cost-saving equipment into your process system at the very beginning can also reap big operating benefits from your investment.

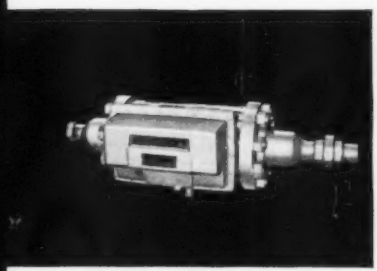
FOR DETAILED INFORMATION on how General Electric system planning can help reduce your process costs, call your local General Electric Industrial Sales Office. General Electric Company, Schenectady 5, N. Y. 651-02

Progress Is Our Most Important Product

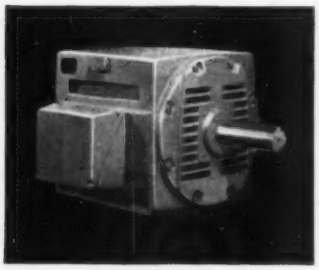
GENERAL ELECTRIC

GENERAL ELECTRIC GAS TURBINES recently installed at a new ethylene process plant are providing reliable, continuous service plus a power bonus by supplying hot exhaust gases for making process steam. Application of G-E gas turbines in your process system can provide similar operating benefits.





NEW TRUE MASS FLOWMETER measures fluid streams directly in pounds, eliminates the time-consuming—and sometimes erroneous—conversion of volume to weight.



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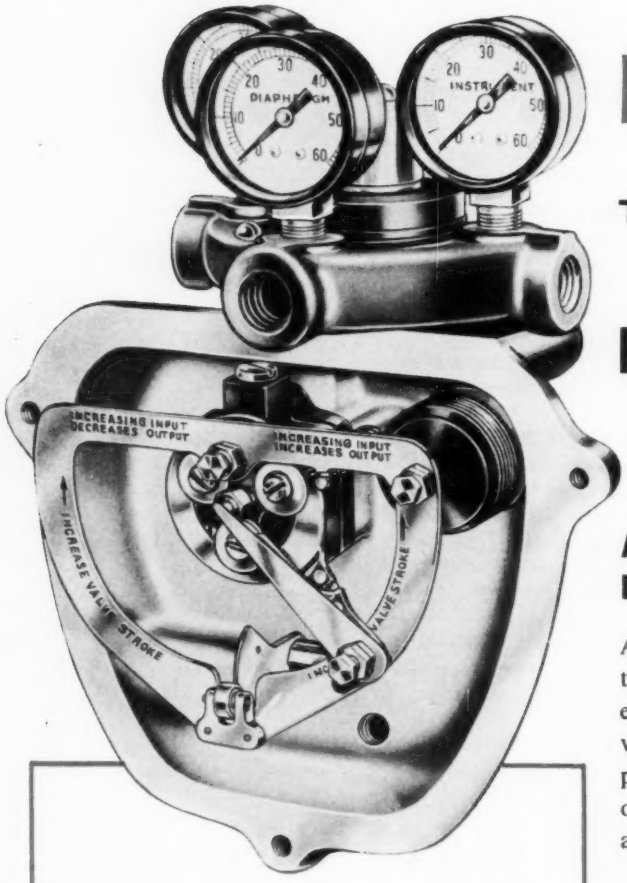
A new concept in design makes possible the...



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V/P

Assured product performance through DYNAMIC ANALYSIS engineering

Application of mathematical techniques of design to pressure control systems has enabled Fisher to eliminate the conventional approach in the development of the new V/P valve positioner. It has provided the V/P with the following combination of characteristics and performance . . . unobtainable in any other type of valve positioner.

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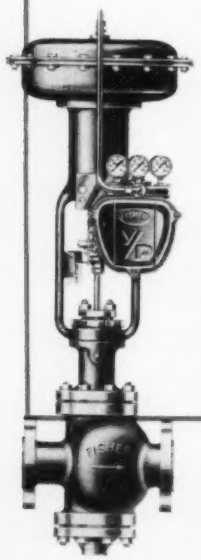

PERFORMANCE DATA

Hysteresis, (Average)	0.0012"
Linearity	as required. Change cams to obtain desired characteristics
Sensitivity	0.14 psi
Resolution Sensitivity	0.002 psi
Repeatability	±0.0003"
Stroking Speed	0.37 in/sec.
Air Consumption	10 scfh
Break Frequency (5% of instrument pressure range)	3.9 cps
Break Frequency (3% of instrument pressure range)	4.6 cps

The above performance data was taken from laboratory tests on a Type 657 diaphragm actuator, Size 40, with 1½" travel. Instrument range 3 to 15 psi.

Write today for Bulletin E-3560

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BUTTERFLY VALVE DIVISION: CONTINENTAL EQUIPMENT COMPANY, CORAOPOLIS, PA.

FISHER® Controls

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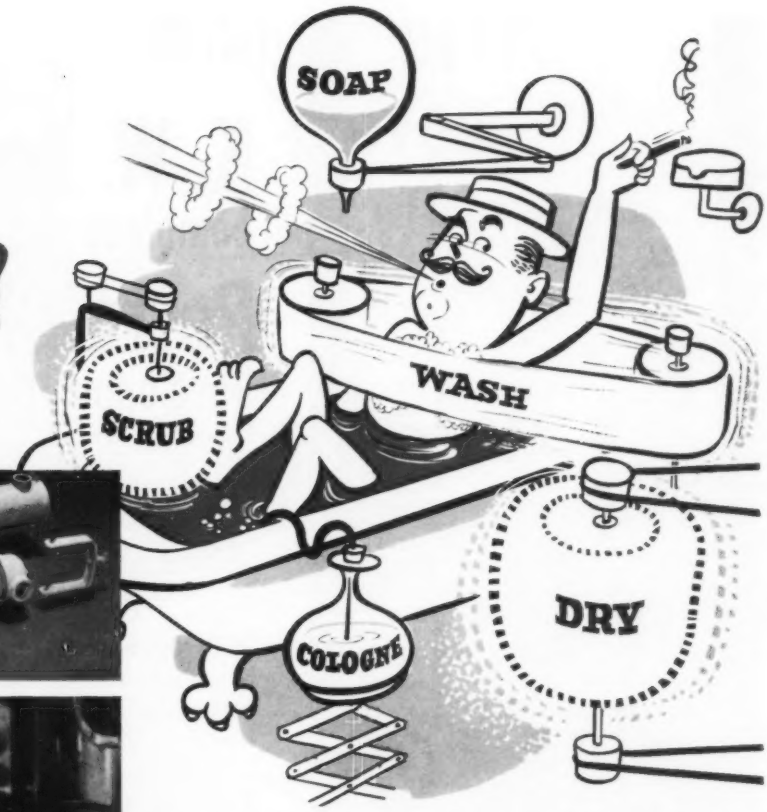

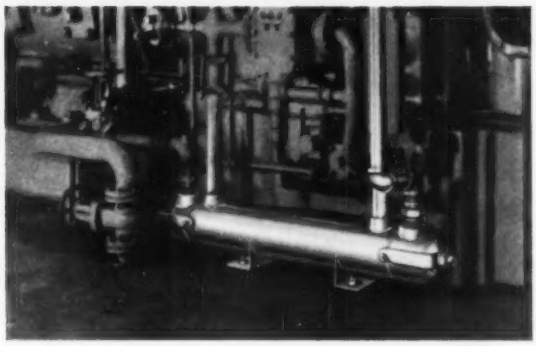

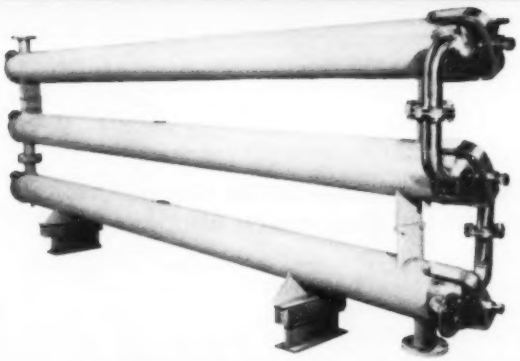

Like our friend portrayed above, the GRAHAM MONOBOLT HEAT EXCHANGER can make yours as easy — but you won't need all the gadgets shown.

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Monobolt makes cleaning a "cinch".

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2. **Minimum down time**
3. **Complete accessibility with no small bolts to strip off**
4. **Full efficiency with rugged construction — no sacrifice in heat transfer**
5. **Economical in first cost AND overall operating cost**
6. **Quick shipment**

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Heliflow Corporation

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For more data on advertised products, use Readers' Service Cards, last page.

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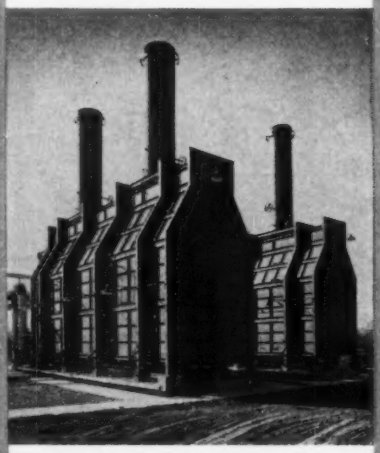

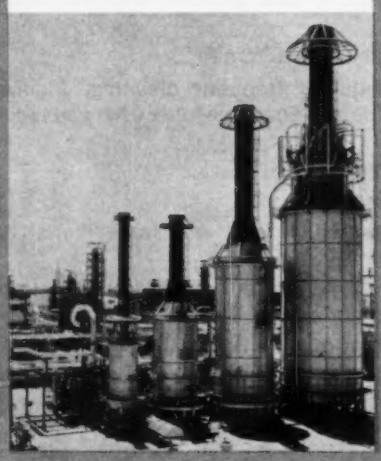

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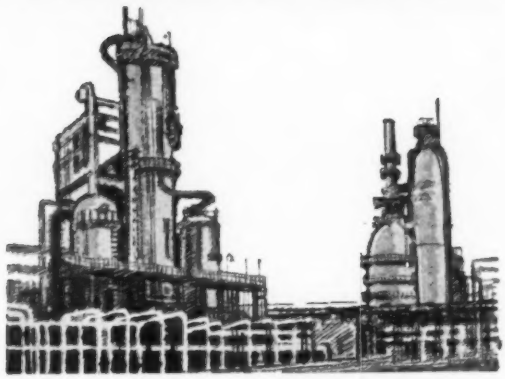

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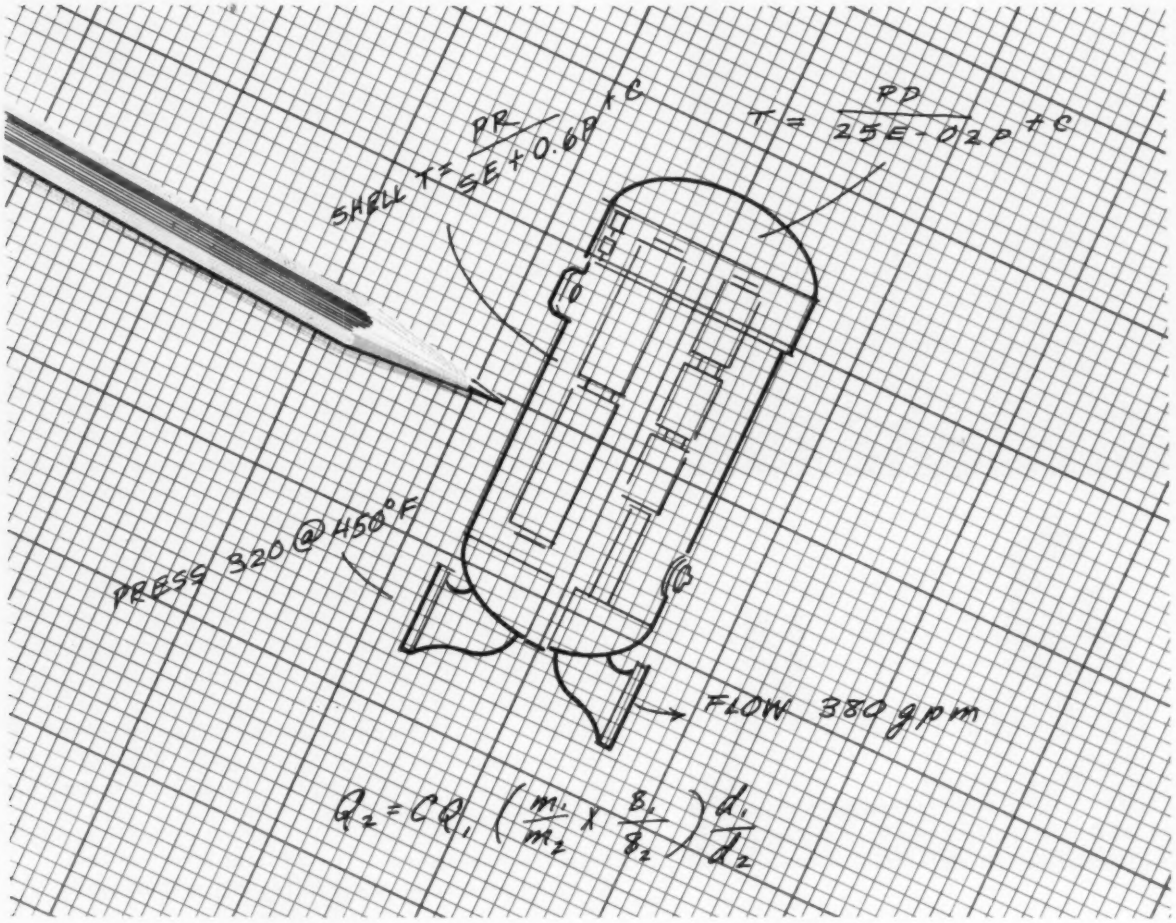

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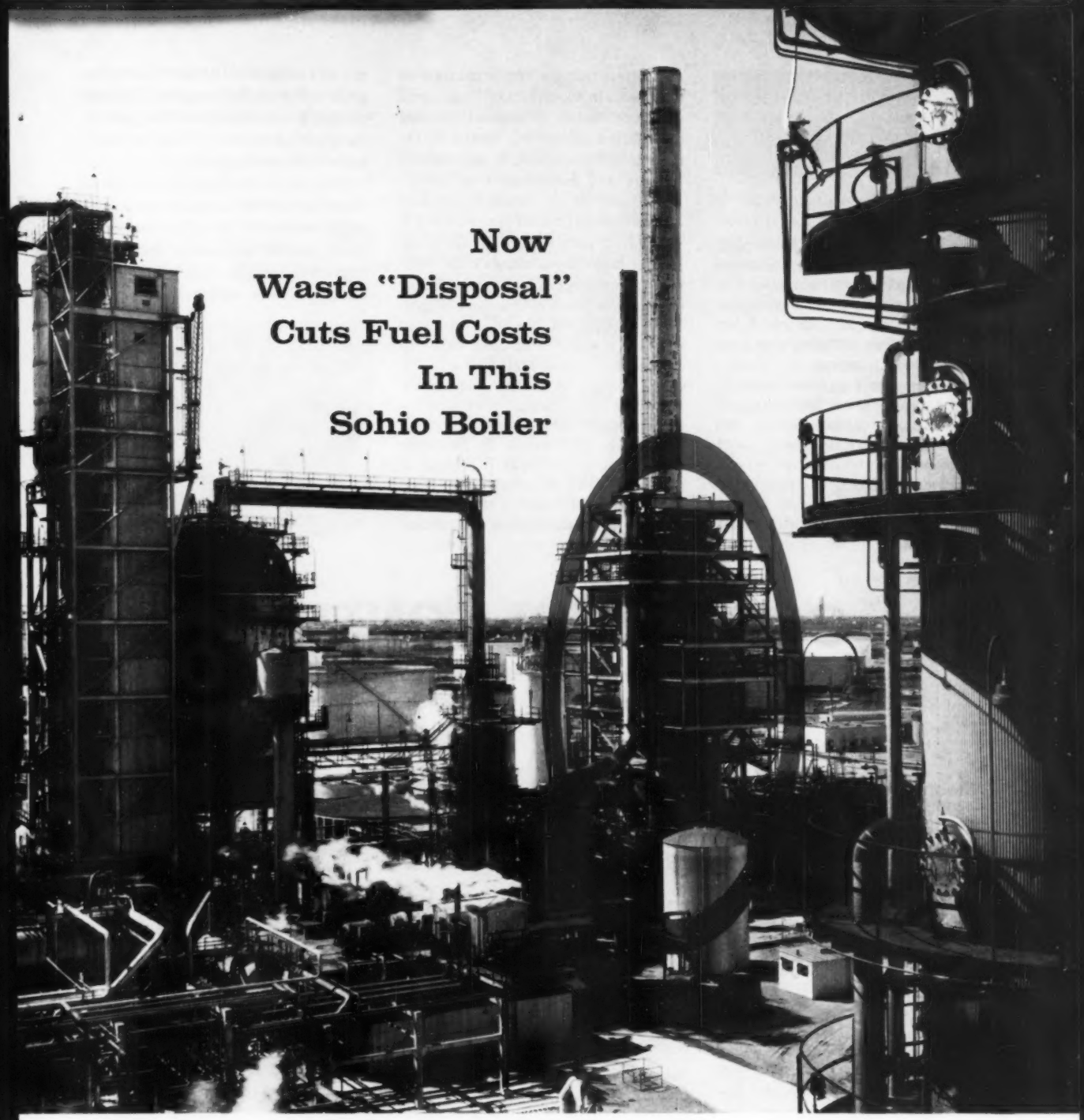

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CO-109

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BOILER DIVISION

HELPFUL WATER CONDITIONING DATA FROM BETZ

CORROSION CONTROL FOR

The modern tools of corrosion control can reduce repair and maintenance costs in your boiler plant.

CORROSION in the modern boiler plant can manifest itself in many locations; such as in the pre-boiler equipment, in the boilers and in the steam and condensate systems. Figures 1, 2 and 3 are typical illustrations of the damage done at some of these locations.

For the most part corrosion is due to dissolved oxygen. Other factors such as low pH values, carbon dioxide and ammonia may be involved, either alone or in conjunction with dissolved oxygen. The preventive measures required to adequately control corrosion involve mechanical equipment and/or chemical treatment.

Mechanical Deaeration

The first line of defense in preventing corrosion is mechanical deaeration. As applied to boiler feedwater, this involves removal of dissolved oxygen in a vented heater by intimately mixing, scrubbing and heating the water with steam. The feedwater heater removes dissolved oxygen, decreases free carbon dioxide and elevates the feedwater to the saturation temperature of the steam. Since exhaust steam is used whenever available, boiler efficiency is also improved. Complex heater designs are required to secure maximum mechanical deaeration. The types of heaters employed include:

1. The *conventional open heater* is most frequently employed in the low pressure boiler plant and is designed to decrease dissolved oxygen to a range of 0.1-0.3 cc per liter.
2. The *deaerating heater* is a unit designed to decrease dissolved oxygen to concentrations of 0.03 cc per liter.
3. The *deaerator* is a unit designed to decrease dissolved oxygen to 0.005 cc per liter or less.

In plants that use simple receivers or open tanks in place of specially designed feedwater heaters, substantial amounts of dissolved oxygen will remain in the feedwater. For example, at atmospheric pressure and temperatures of 120 F, 150 F and 180 F, residual dissolved oxygen concentrations expected are 5.7, 4.3 and 1.5 ppm respectively. It is important therefore to maintain the feedwater temperature as high as possible for maximum removal of dissolved oxygen. The supplemental use of a chemical deaerant is essential in these plants to control corrosion and pitting due to dissolved oxygen. A second essential requirement is that the feedwater temperature be maintained at a consistently high level. Wide fluctuations in feedwater temperature would make it difficult, if not impossible, to regulate the feed of the chemical deaerant to cope with the varying concentrations of residual oxygen.

Figure 1—Pitting in boiler drum.

Chemical Deaeration

Sodium sulfite is the chemical agent favored for chemical deaeration in all but the high pressure plants because of its low cost and ease of handling. Where speed of reaction is important a catalyzed sodium sulfite is available which will react instantaneously with dissolved oxygen. The reaction of sodium sulfite with dissolved oxygen is illustrated as follows:

$$2Na_2SO_3 + O_2 = 2Na_2SO_4$$
$$\text{sodium sulfite} + \text{oxygen} = \text{sodium sulfate}$$

To remove 1.0 ppm of dissolved oxygen approximately 10 ppm of technical grade sodium sulfite is required. The end product is sodium sulfate which adds to the dissolved solids content of the water, but is otherwise innocuous.

While chemical deaeration is essential where incomplete mechanical deaeration of the feedwater is accomplished, it is a much desired supplement even when employing specially designed feedwater heaters. The low additional cost of the chemical deaerant in these cases is justified as it provides:

1. Complete oxygen removal.
2. An added safety factor in the event of momentary interruptions in efficiency of mechanical deaeration.
3. Warning when the efficiency of mechanical deaeration is continuously low.
4. Protection of the pre-boiler equipment, such as feed pumps, feedlines, stage heaters and economizers.

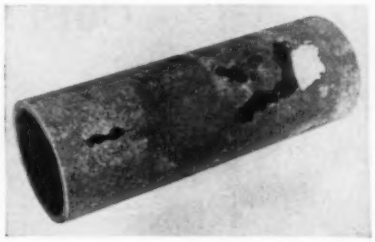

Figure 2—Condensate line attack by carbon dioxide.

In many plants, the most suitable point of application is the storage compartment of the feedwater heater. In other plants, sufficient reaction time may be available with continuous feed to the suction side of the boiler feed pump.

As boiler operating pressures have increased, two disadvantages of sodium sulfite as a chemical deaerant have become evident. While the increase in dissolved solids produced by the end product sodium sulfate is of little consequence in low or medium pressure boilers, it can be of significance in high pressure boilers. Also, at high pressures, the residual sulfite required for control

purposes, tends to decompose to form the acidic gases, sulfur dioxide and hydrogen sulfide which can contribute to corrosion in the steam and condensate systems. For these reasons, hydrazine finds favor as a chemical deaerant in high pressure boiler systems. Hydrazine removes dissolved oxygen in accordance with the following reaction:

$$N_2H_4 + O_2 = 2H_2O + N_2$$
hydrazine + oxygen = water + nitrogen

Since the products of this reaction are water and nitrogen no dissolved solids are added to the boiler water. In addition, the decomposition products of the residual hydrazine are ammonia and nitrogen. The ammonia is alkaline and will not attack steel. However, it is essential to avoid high residuals of hydrazine otherwise the ammonia produced may have an adverse effect on copper and copper bearing alloys.

Except for special cases of corrosive attack involving high pressure boiler operation, experience has shown that it is desirable to maintain a minimum boiler water pH of approximately 10.5. This pH is sufficiently high to prevent corrosion of the boiler proper. Usually, in the low and moderate pressure range, boiler water alkalinity is set at sufficiently high levels primarily to assure the proper environment for precipitation of calcium and magnesium sludge. These levels assure at least the minimum pH necessary for proper protection of the boiler against acidic corrosion.

In high pressure boilers the alkalinity level is restricted to avoid "free caustic" and thus prevent embrittlement and other adverse effects.

Carbon dioxide has little bearing on corrosion of the pre-boiler system or the boiler proper. Efficient mechanical deaeration will decrease the free carbon dioxide of the boiler feedwater and as a result the pH of the feedwater will increase. The increase in pH thus produced together with the feed of a chemical deaerant usually affords adequate protection to the pre-boiler system. In some cases, the supplemental feed of caustic soda may be employed to further increase the pH of the feedwater and to speed the reaction of the chemical deaerant.

The concern with carbon dioxide is primarily due to its adverse effect in the steam and condensate system. The natural bicarbonate alkalinity of the feedwater decomposes when subjected to boiler temperature, yielding carbon dioxide which leaves the boiler with the steam. At points of condensation low pH will develop from the carbonic acid formed and corrosion will ensue. Prevention of steam and condensate corrosion can effectively and economically be accomplished by use of the film forming or neutralizing amines.

Protection of Idle Equipment

All too often, little attention is given to idle equipment in the boiler plant until serious corrosion has developed. Special measures are necessary to protect idle boilers and steam turbines. The methods applicable depend on many factors but suitable procedures can be worked out for most conditions.

THE BOILER PLANT

Figure 3—Corrosion of turbine blades.

Other Factors

While mechanical and chemical deaeration will serve to cope with dissolved oxygen—the major cause of corrosion in boiler plants—pH and carbon dioxide are factors that must also be considered.

Betz Laboratories has pioneered in the development and practical application of many boiler corrosion prevention techniques. With an extensive background of experience in this field, we are ready to help solve your particular problem effectively and economically. A Betz Field Engineer will be happy to call on you, without obligation.

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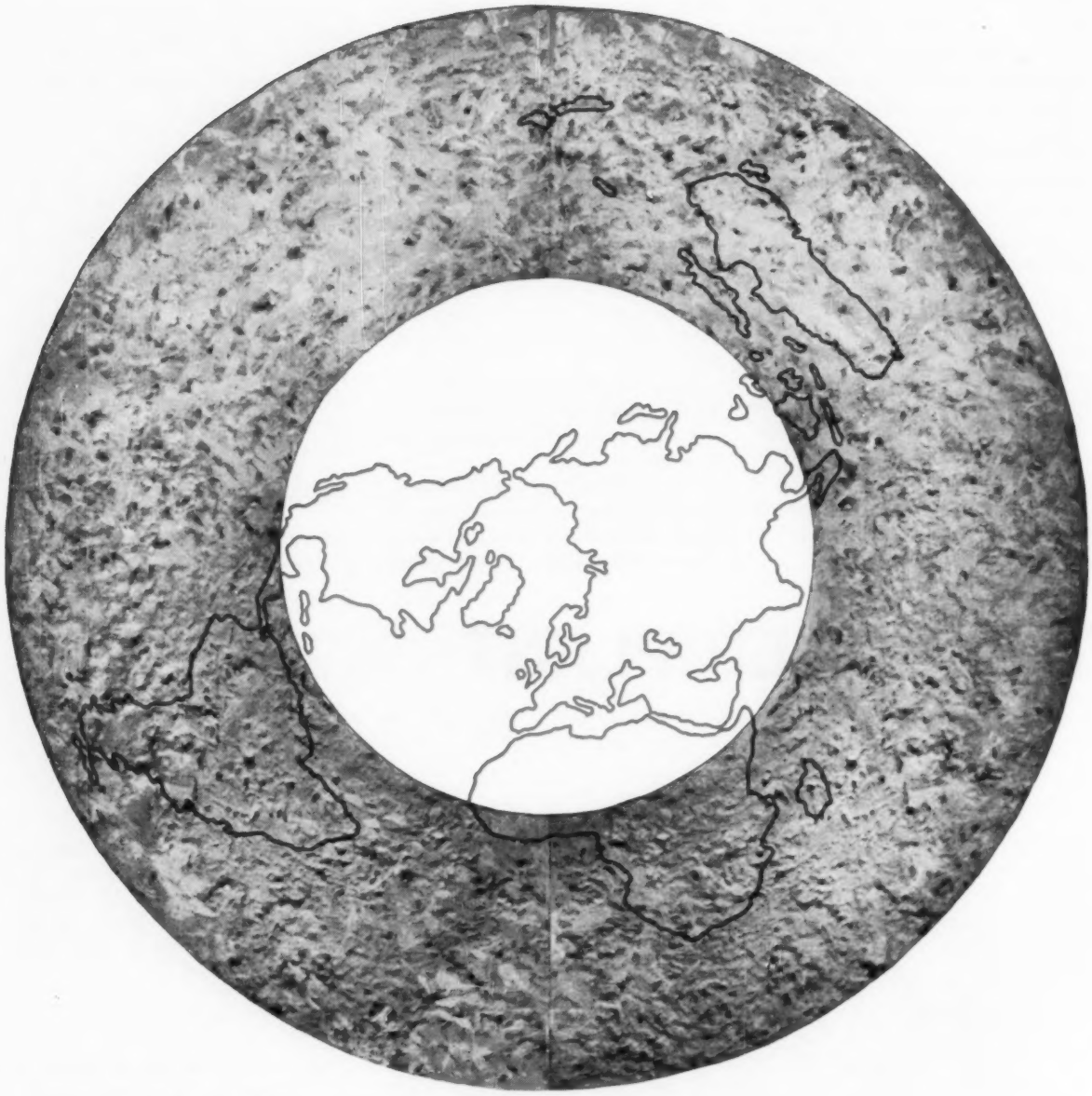

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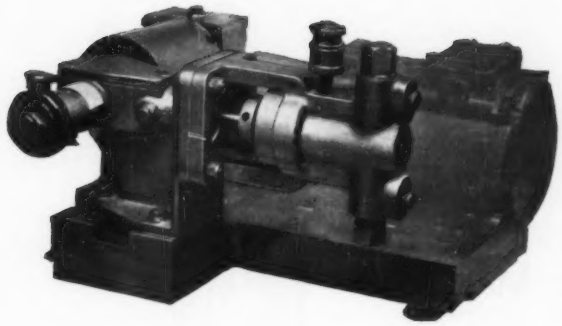

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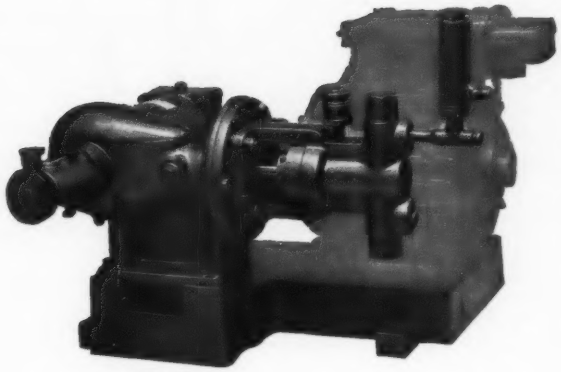

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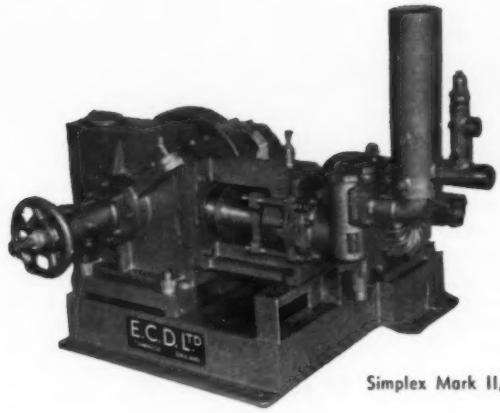

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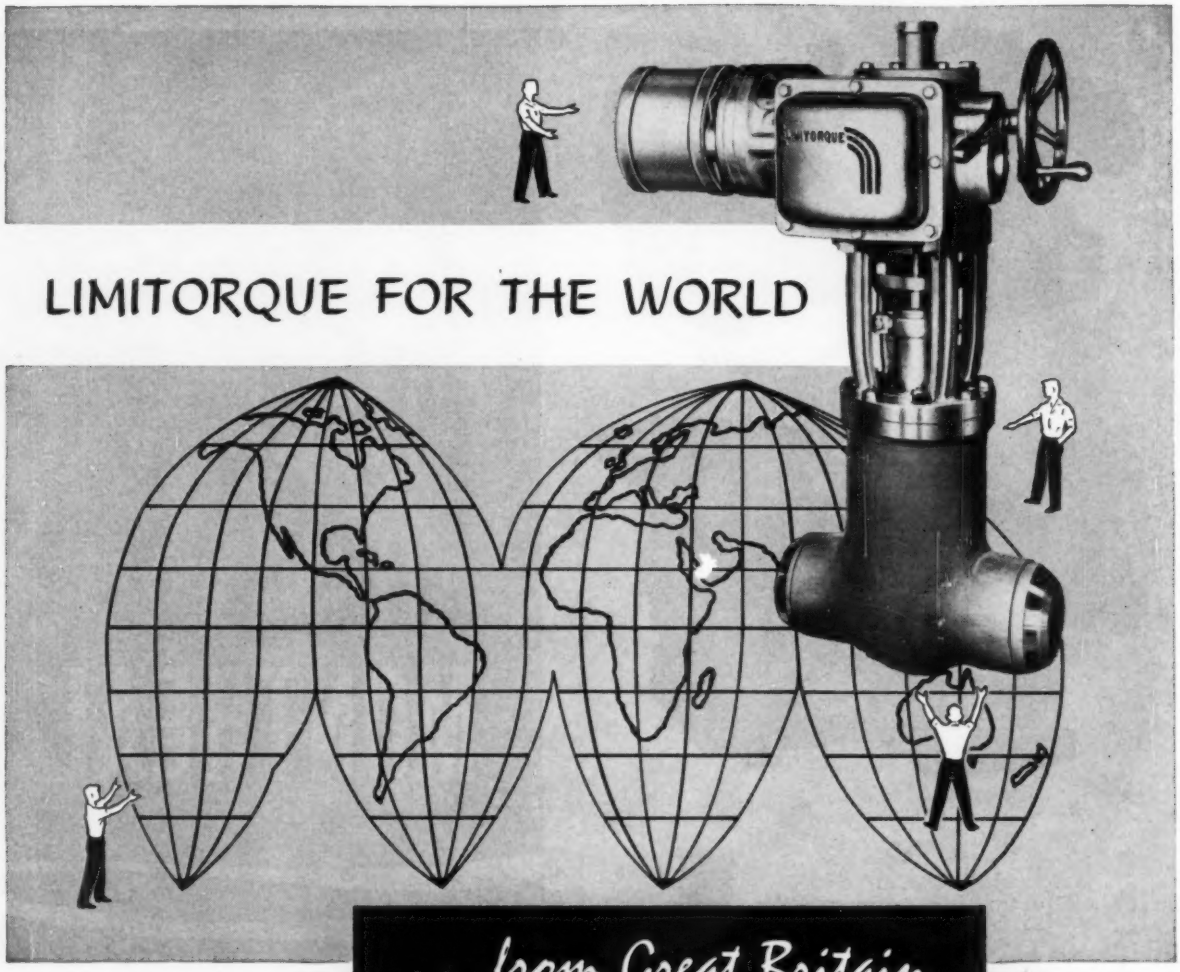

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MATERIALS FOR PROTECTION OF THERMAL INSULATION AGAINST FIRE DAMAGE

FIRST, to clear up a common misconception about materials used to protect thermal insulation; no coating, sealer, or adhesive can by itself prevent fire damage. In fact, certain products without fire-retardant properties many times will actually cause fire and flames to spread; while products containing fire-retardant properties can at best only retard the spread of flames by the reduction of available fuel.

Over the years many ambiguous and ill-defined terms have been used to describe fire resistant properties of materials in literature, specifications and other published data. Words and phrases such as incombustible, flame-proof, non-flammable, fire resistive, and even fireproof have been attached to products used for the protection of thermal insulation. In many cases where the use of these terms was based on unrecognized and inadequate test methods, the products actually fed fuel to the flames rather than retarding them.

The only accepted measure of fire hazard in coatings is the flame-spread value. The confusing phrases used above do not give in exact terms the flame-spread value. If the confusion is to be eliminated, Industry must adopt a standardized system of testing and terminology for use in Engineering Specifications.

The use of confusing terms can be discarded by the adoption of the rating standard known as the Flame-Spread Index, accepted and used by building codes and insurance underwriters. There are two test methods accepted by Industry for determining flame-spread values. These are the Underwriters' Laboratories' "Tunnel Test" (ASTM E84) and the National Bureau of Standards "Radiant Energy Test" (Interim Federal Standard .00136–Com. NBS). With either of these established methods, flame-spread values ranging from zero to over 200 can be determined with accuracy for all coatings, adhesives and sealers used with thermal insulation materials.

An example of flame-spread values:

A totally incombustible material such as portland cement would have a flame-spread value of zero, while a self-extinguishable synthetic resin product could be rated about 60, and a violently combustible nitrocellulose product would be rated at "over 200."

Here, also, are the flame-spread values of some popular insulation weathercoatings applied over calcium-silicate insulation:

VAPOR BARRIER ASPHALT MASTIC	
Product A	175
Product B	173
Foster C. I. Mastic 60-26	170
FIBRATED ASPHALT EMULSION MASTIC	
Product A	218
Product B	200
Foster H. I. Mastic 90-07	150
FIBRATED POLYMER EMULSION MASTIC	
Product A	290
Foster Sealfas Mastic	40
FIRE RESISTIVE VAPOR BARRIER MASTIC	
Foster Fire Resistive Mastic 60-60	35

The Solvent Problem

Flame-spread values of solvent type mastic weathercoatings are determined under solvent free conditions to simulate service conditions existing after the products have been applied and all traces of solvent have evaporated. However, during application and cure, a fire hazard will exist when flammable solvents are contained in the coating. Such solvents having a flash point lower than 100° F. are flammable and easily ignited by welding sparks, matches, electrical sparks, cigarettes, etc. Thus a product, whose flame-spread index under solvent free conditions is relatively low, could well be the cause of a disastrous fire while it is being applied if it contains a flammable solvent.

Therefore, for complete fire safety, where welding and other sources of sparks and flame cannot be avoided during application of coatings and adhesives, these products should be chosen not only for their ultimate flame-spread value, but also for their formulation with non-flammable solvents (for example, Foster Fire Resistive Mastics).

Recommendations

We urgently recommend that engineers who specify fire resistive coatings, sealers and adhesives for use with thermal insulation specify maximum acceptable flame-spread values and flash points of materials. Only by rigidly adhering to such specifications will owners, their inspectors, buyers and applicators obtain fire safe thermal insulation construction.

A Word of Caution

The mere publishing of a flame-spread value is insufficient evidence on which to choose a product. Where two products, equivalent in every other respect, are offered for fire safe service, a product with a flame-spread value of 6 should unquestionably be chosen over a product whose index is 44. *Relative* flame-spread values, then, become of vital importance in choosing fire-retardant products.

Purpose

We at the Benjamin Foster Company have been devoting many years to research, study, manufacture and promotion of fire safe products for use in the protection of thermal insulation. We have adopted a firm policy regarding our promotion of fire safe products which is:

"To cooperate with all interested individuals and organizations in the establishing of a standardized system of testing and rating true flame-spread value . . .

To publish information that will be factual and in accordance with accepted practices . . .

To avoid overemphasis of disaster conditions in the promotion of fire safety . . .

To continue our research and development of products with improved fire safe characteristics."

If there is any way we can be helpful to you or your organization in a better understanding of products for use in the protection of thermal insulation, please contact your nearest Foster Representative, or write Benjamin Foster Company, 4635 W. Girard Avenue, Philadelphia 31, Pa.

foster COATINGS · SEALERS · ADHESIVES for thermal insulation

DIVISION OF AMCHEM PRODUCTS

For more data on advertised products, use Readers' Service Cards, last page.

So Long... Until Tomorrow It took five flat cars to ship this 195 foot-long fractionating column from our Orange, Texas, plant. Even the Texans thought it was a whopper, but tomorrow we'll be fabricating bigger ones—that's the way it goes. ☐ This column went to a leading refinery where it produces high purity isobutane, a component of premium gasoline. ☐ The 12-foot diameter steel column is made up of 20 rings or sections, each ¾ of an inch thick. The rings are welded together, then welded to a 20-foot skirt which supports the tower in its upright position. After fabrication the column was stress relieved.

Our Orange, Texas plate shop can handle custom plate work of all kinds and sizes. We have experienced men and the right equipment, high capacity cranes, giant presses and bending rolls, the latest welding equipment, mammoth car bottom furnaces, and complete inspection facilities. We can ship by rail, truck or barge. And anything we make, we can erect. ☐ Write for our booklet on plate fabricating facilities and services.

USS is a registered trademark

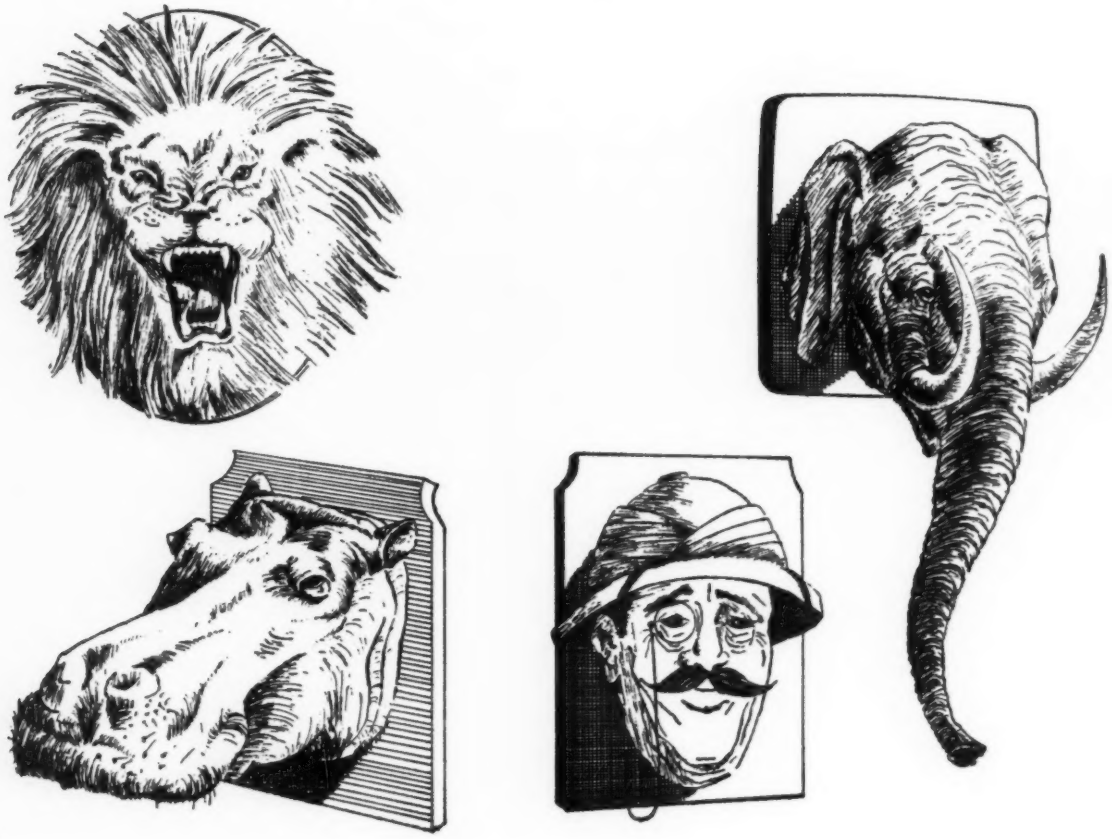
This mark tells you a product is made of modern, dependable Steel.

General Offices: 525 William Penn Place, Pittsburgh, Pa.
Contracting Offices in: Ambridge • Atlanta • Baltimore • Birmingham Boston • Chicago • Cincinnati • Cleveland • Dallas • Denver • Detroit Elmira • Gary • Harrisburg, Pa. • Houston • Los Angeles • Memphis Minneapolis • New York • Orange, Texas • Philadelphia • Pittsburgh Portland, Ore. • Roanoke • St. Louis • San Francisco • Trenton United States Steel Export Company, New York

American Bridge Division of United States Steel

USS

Which lives longest?



Can you tell the real thing when you see it?

Facts are frequently surprising.

Case in point: You may be in a position to receive caustic by barge, and not know it. Our studies show that this is true of a surprising number of caustic users. If there's a chance that you are one of them, get in touch with us. We produce caustic at Geismar, Louisiana and Wyandotte, Michigan . . . ship it from either point by barge or ocean tanker, truck or tank car. Let us help find the right answer for you. It may save you money.

Wyandotte offers a number of chemicals for the petroleum industry, including materials for drilling muds, gas dehumidification, demulsifying, emulsifying, secondary recovery, water treatment, cementing, sweetening, and many other petroleum, refinery, and petrochemical applications. Get full details from your distributor, or write: *Wyandotte Chemicals Corporation, Wyandotte, Michigan. Also Baton Rouge, Louisiana. Offices in principal cities.*

ANSWER: If you picked the elephant, you're half right. Men and elephants have about the same life span. The lion lives 15 to 20 years, and the hippo about 30.

• • • • •

WYANDOTTE CHEMICALS

MICHIGAN ALKALI DIVISION

Pacing progress with creative chemistry

CYANAMID BRINGS YOU A NEW
HYDROGEN TREATING CATALYST

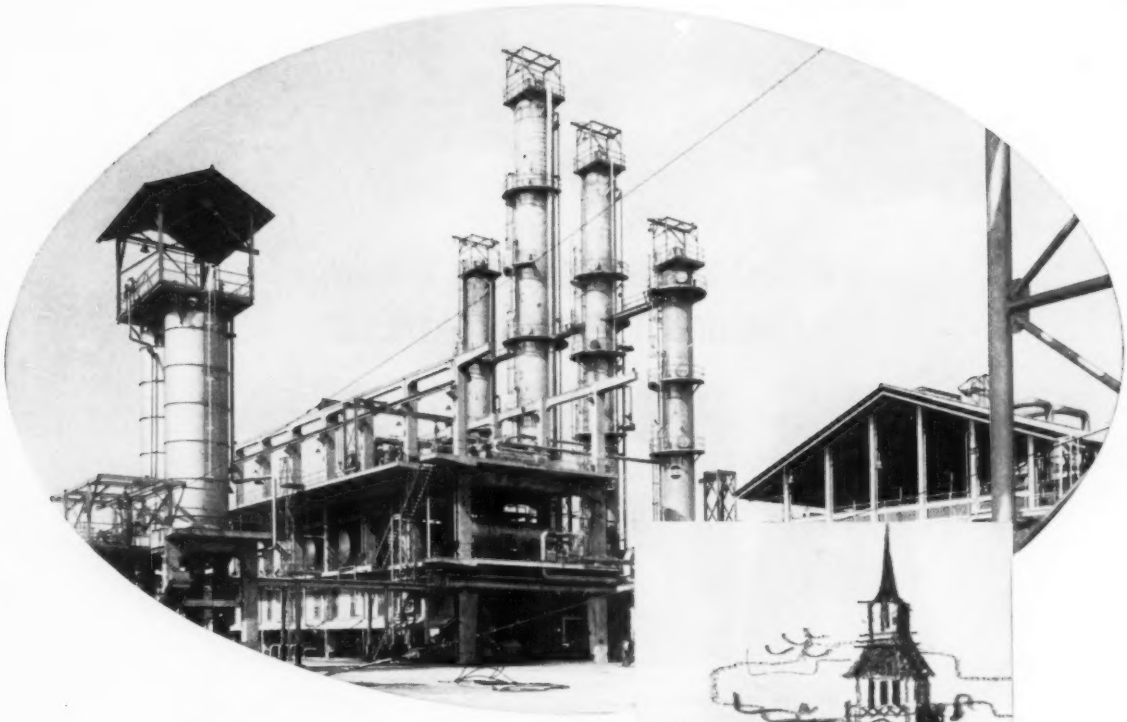
AERO® HDS-3

Now you can have the benefit of desulfurization with markedly increased nitrogen and polyaromatics removal over cobalt-molybdenum catalyst compositions. Particularly well adapted for giving improved color to waxes, treatment of nitrogen-containing naphthas, or hydrogenation of cat cracker feedstocks and middle distillates. AERO HDS-3 is a new addition to Cyanamid's line of catalysts. Write for further information.

BASIC IN CATALYST CHEMISTRY.

CYANAMID

AMERICAN CYANAMID COMPANY • REFINERY CHEMICALS DEPARTMENT • 30 Rockefeller Plaza, New York 20, N. Y.



PENNY WISE . . . DOLLAR WISER!

Your process construction dollars buy more . . . when you entrust the job to Procon. Construction-wise Procon purchasing men, engineers and other personnel, go all out to get you the most for your money:

They balance cost against performance . . . hold purchases strictly in line with your budget . . . check and recheck components large and small for materials, tolerances, stresses . . . provide a running account of purchases, a constantly current balance sheet, down to the last penny.

Procon builds plants that perform as intended . . . with materials, parts and components bought the way you'd buy them yourself, if you had the necessary time, facilities and personnel.

PROCON *Incorporated*

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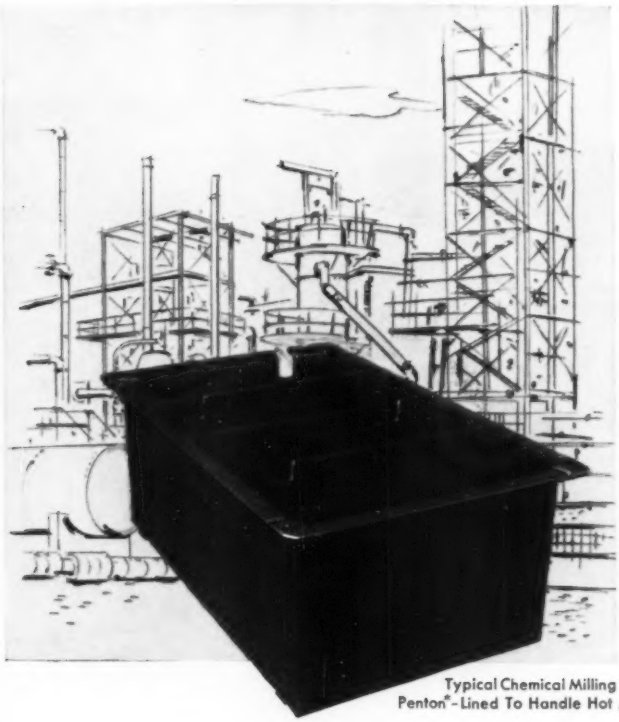
WORLD-WIDE CONSTRUCTION FOR THE PETROLEUM, CHEMICAL AND PETROCHEMICAL INDUSTRIES

GAR-LINE PENTON TANK LININGS

for Corrosion Resistant Service



Typical Chemical Milling Tank Penton*-Lined To Handle Hot Acids

New GAR-LINE Penton Tank Linings offer economical, high-temperature protection against corrosion. Where only more expensive materials were previously used, GAR-LINE Penton Tank Linings are proving their ability to perform as well as—and better—in many corrosive exposures at high temperatures.

Unique Properties. Mechanically, GAR-LINE Penton Tank Linings exhibit excellent tensile strength at high temperatures, good dimensional stability and low water absorption . . . Chemically, they resist all inorganic acids except fuming nitric and fuming sulfuric.

Applied by carefully selected and authorized applicators. The experience of these tank lining experts guarantees satisfactory GAR-LINE Penton installation, prevents expensive failure due to improper application. Approved applicators include:

ABRASION & CORROSION ENGRS.
1205 N. McMasters Street
Amarillo, Texas

AUTOMOTIVE RUBBER CO., INC.
12580 Beech Road
Detroit 39, Michigan

BARTHEL CHEMICAL CONST., CO., INC.
P.O. Box 1025
Tacoma 1, Washington

BELKE MFG. CO., INC.
947 N. Cicero Avenue
Chicago 51, Illinois

BITTNER INDUSTRIES, INC.
91 Diaz St.
P.O. Box 10265
Prichard, Alabama

BUCKLEY IRON WORKS
21 Christopher Street
Dorchester, Mass.

BUFFALO LININGS
73 Gillette Avenue
Buffalo 14, New York

CHEMICAL PROOF OF SEATTLE
625 Alaska Street
Seattle, Washington

ELCHEM ENGRG. & MFG. LTD.
2025 James Street
Burlington, Ontario, Canada

ELECTRO CHEMICAL ENGRG. & MFG. CO.
750 Broad Street
Emmaus, Pennsylvania

THE FORTUNE COMPANY
1906 N. Mosley
Wichita 14, Kansas

GOODALL RUBBER COMPANY
2050 N. Hawthorne Avenue
Melrose Park, Illinois

HANSZEN PLASTICS COMPANY
835 S. Good-Latimer Expressway
Dallas, Texas

INNER-TANK LINING CORP.
4777 Eastern Avenue
Cincinnati 26, Ohio

MAURICE A. KNIGHT
Kelly Avenue
Akron 9, Ohio

MERCER RUBBER CORPORATION
Highway 46, Cor. Huyler
Little Ferry, N. J.

METALWELD, INC.
Scotts Lane & Abbottsford Rd.
Philadelphia 29, Pa.

PARKER BROTHERS, INC.
7044 Bandini Blvd.
Los Angeles 22, California

PLASTIC APPLICATORS INC.
7020 Katy Rd.
P.O. Box 7631
Houston 7, Texas

RUBBER MILLERS, INC.
707 S. Caton Avenue
Baltimore, Maryland

ST. LOUIS METALLIZING CO.
625 S. Sarah Street
St. Louis 10, Missouri

STEBBINS ENGRG. & MFG. CO.
Watertown, New York

GARLOCK

Investigate GAR-LINE Penton Tank Linings as the answer to your corrosion problems. For more information, contact the applicator nearest to you. Or, write for data on Penton; information also available on Teflon Anti-Stick and Teflon† Tank Linings. Special Products Dept., Garlock Inc., P.O. Box 612, Camden 1, New Jersey.

*Registered Trademark, Hercules Powder Company
†Registered Trademark, The DuPont Company

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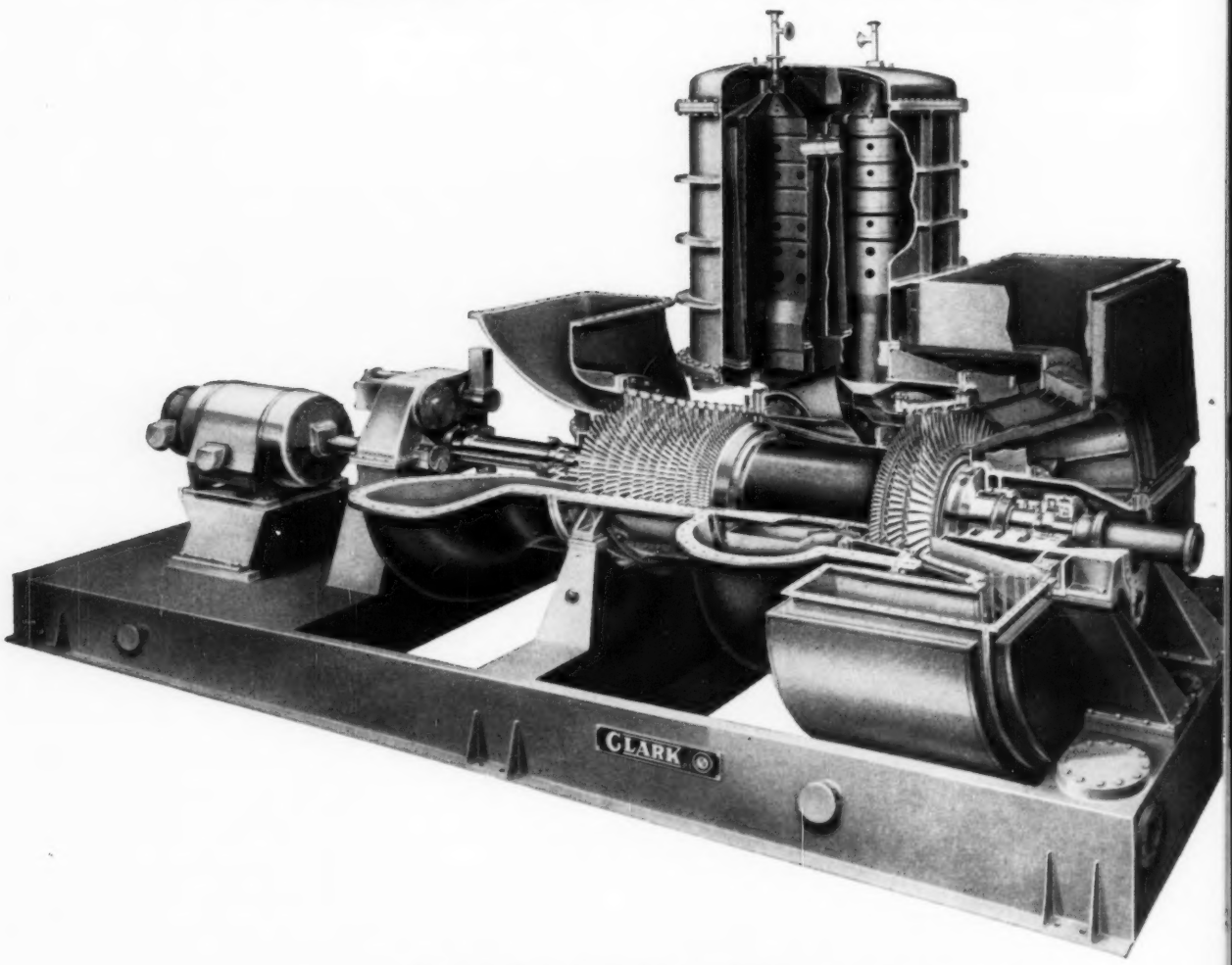
No matter how you gauge PRIME MOVER COST...



CLARK BROS. CO., OLEAN, N.Y.

CLARK

DRESSER INDUSTRIES INC.
OIL • GAS • CHEMICAL
ELECTRONIC • INDUSTRIAL

ENGINES • GAS TURBINES • COMPRESSORS

the CLARK 300 series of GAS TURBINES measures up fully to your needs

Name the norm . . . capital investment, floor space, installation or operating labor, general reliability, maintenance or all combined. Whatever you use to determine *real* prime mover cost, Clark heavy duty industrial gas turbines provide the most economical answer to your requirements. As an example of how these advantages work for you let us examine the latest addition to the Clark 300 series of turbines, the Model 305-S.

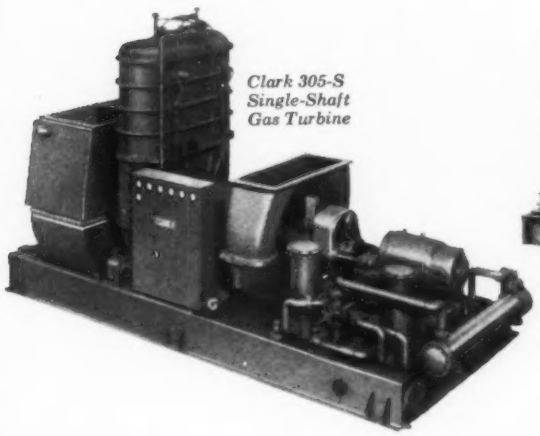
CONSIDER INITIAL INVESTMENT—This single-shaft open cycle machine is simplicity itself. With the axial compressor and three stage turbine mounted on the same shaft, parts . . . *and cost* are cut to a minimum.

FIELD PROVED RELIABILITY—Important components such as compressor and turbine blading are based on proved designs which have operated for thousands of hours in Clark Dual-Shaft Gas Turbines. Turbine inlet temperature is held under 1400° F to ensure extra long life and to provide a substantial margin of operating safety. The turbine is completely air cooled and suitable for operation in arid country. Pressurized air is bled off the axial compressor to cool turbine blade roots and other high temperature components. In addition, cool air envelopes between inner and outer skin surfaces reduce heat loss and minimize heat radiation.

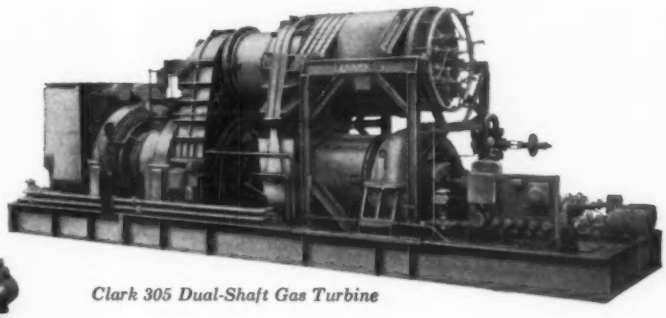
FLOOR SPACE INSTALLATION AND MAINTENANCE—The Clark 305-S is so compact it is mounted on a skid only 26 feet long. The combustion chamber with two parallel burners is placed over the rotor between compressor and turbine. You save on floor space, housing, transportation to the site, foundation and installation expense. Both the single and dual-shaft Clark gas turbine designs have provisions for easy access to blading, bearings and seals for inspection or maintenance.

VERSATILE TOO—Clark Series 300 Gas Turbines in the 8000-10,000 horsepower class provide the inherent flexibility to match the application. The dual-shaft models are excellent drivers for pumps or compressors on liquid or gas transmission lines, for marine propulsion, compressor drivers in repressuring or process plants and other uses requiring broad speed and loading flexibility. For applications that do not require the wide range flexibility of the dual-shaft machine such as base load or peaking turbogenerators the single-shaft units are ideal. Both designs burn either liquid or gaseous fuels.

Your Clark representative will gladly give you all of the cost saving details on Clark Gas Turbines. Consult him or write us direct. CLARK BROS. CO., OLEAN, NEW YORK.



Clark 305-S Single-Shaft Gas Turbine



Clark 305 Dual-Shaft Gas Turbine

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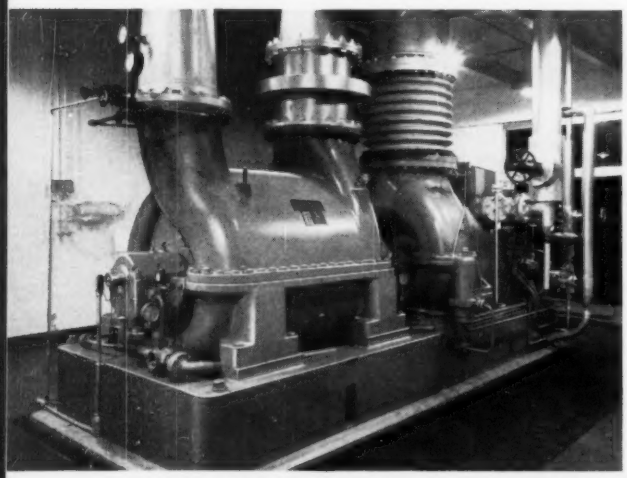
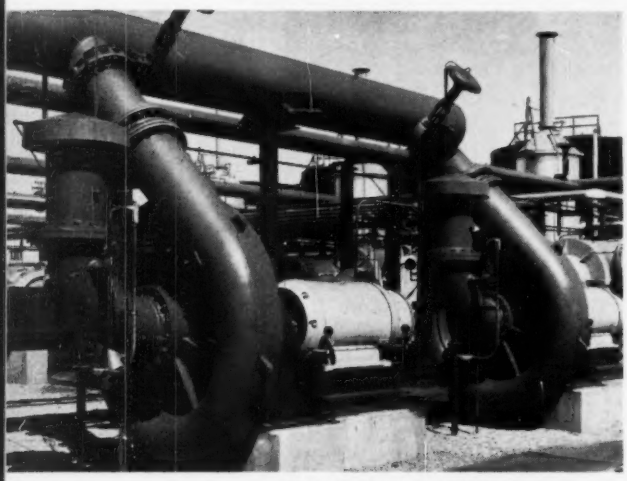
in Chemical and Petroleum Refining Service–

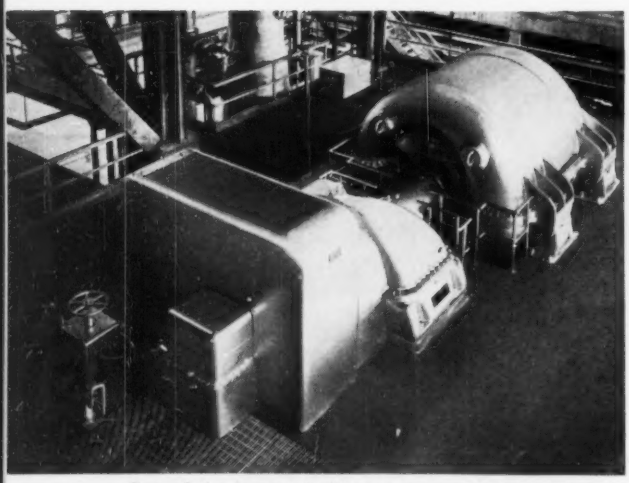
ELLIOTT



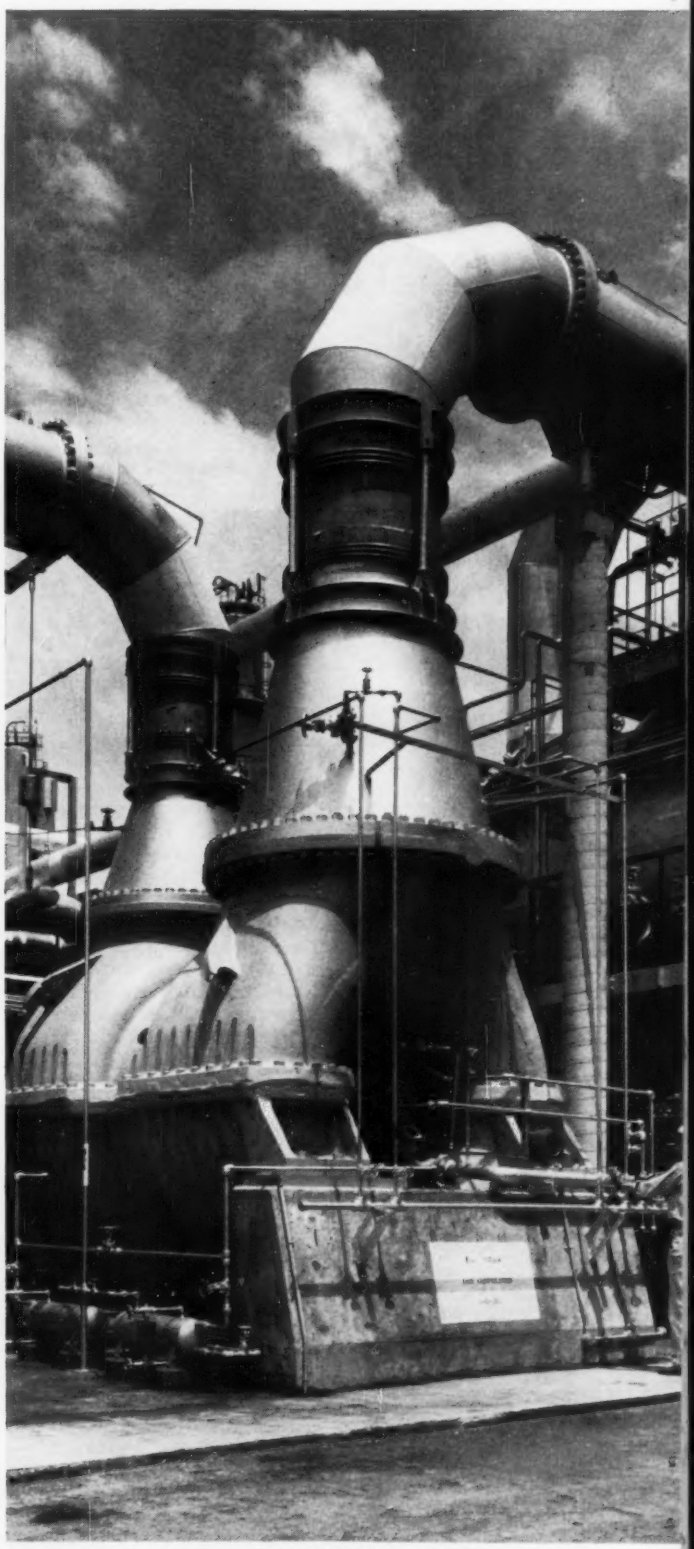
Elliott multi-stage compressor with 2035-hp Elliott turbine drive, in refinery service.



Two single-stage Elliott compressors driven by Elliott motors.



One of the largest turbine-driven multi-stage compressors ever installed, for fluid catalytic cracking unit.



One of the large axials serving a Petro-Chemical plant.

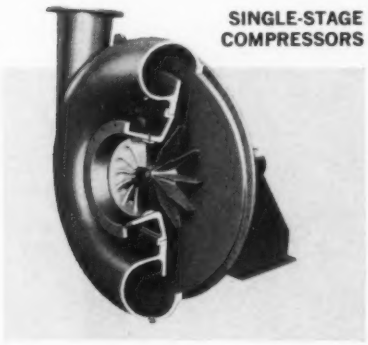
COMPRESSORS

Today's most complete line of centrifugal and axial machines from **500** *cfm to* **600,000** *cfm*

48 FRAME SIZES WITH MATCHING DRIVERS

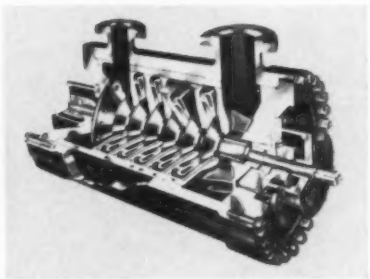
With this, the most-complete line of centrifugal and axial compressors available today—Elliott offers an unexcelled range of choice of established machines. In addition, there is the extra advantage of matching Elliott turbine or motor drivers. Both units engineered and built by Elliott is a decided "plus" because it means unified responsibility, unified service.

SINGLE-STAGE COMPRESSORS



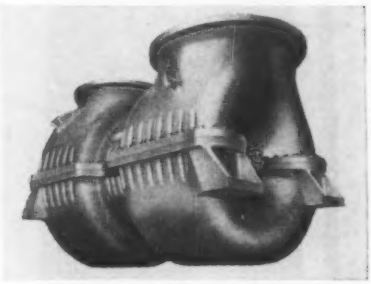
Elliott single-stage centrifugal compressors range in size from 700 to 100,000 icfm and above. They are readily adaptable to special service conditions, and to the handling of corrosive or dirty gases. A variety of impeller designs, bearings, seals, and materials of construction permits each unit to be tailored to its particular application.

MULTI-STAGE CENTRIFUGAL COMPRESSORS



Elliott multi-stage compressors are made in a wide variety of sizes and styles, to serve many difficult and exacting applications. They are available with inlet capacities up to approximately 150,000 icfm. Impellers, casings, internal passages and bearings for each type of machine have been designed to provide smoothly operating, rugged, dependable machines.

AXIAL FLOW COMPRESSORS



Multi-stage compressors of the axial flow type are designed and engineered specifically to serve the needs of industry for the handling of air or gas mixtures in large volume flow operation. Applications include petroleum refining, chemical processing and the steel industry. Frame sizes are rated up to approximately 600,000 cubic feet per minute when operating on air.

MATCHED MOTOR OR TURBINE DRIVE

Elliott is a leading manufacturer of both steam turbines and electric motors, of all types and ratings necessary to provide driving power for the compressor units described above. Consequently, we are in position to recommend and furnish the type of drive best suited for each application.

FOR AIR OR GASES

Elliott integrated compressor units are available for handling all types of compressible fluids, within the pressure and flow limits of the machines. Where corrosive gases are handled, special materials are employed in vulnerable spots; where high pressures are needed, extra heavy construction is used; where leakage must be prevented, special shaft seals are available; where high temperatures must be avoided, provision is made for cooling.

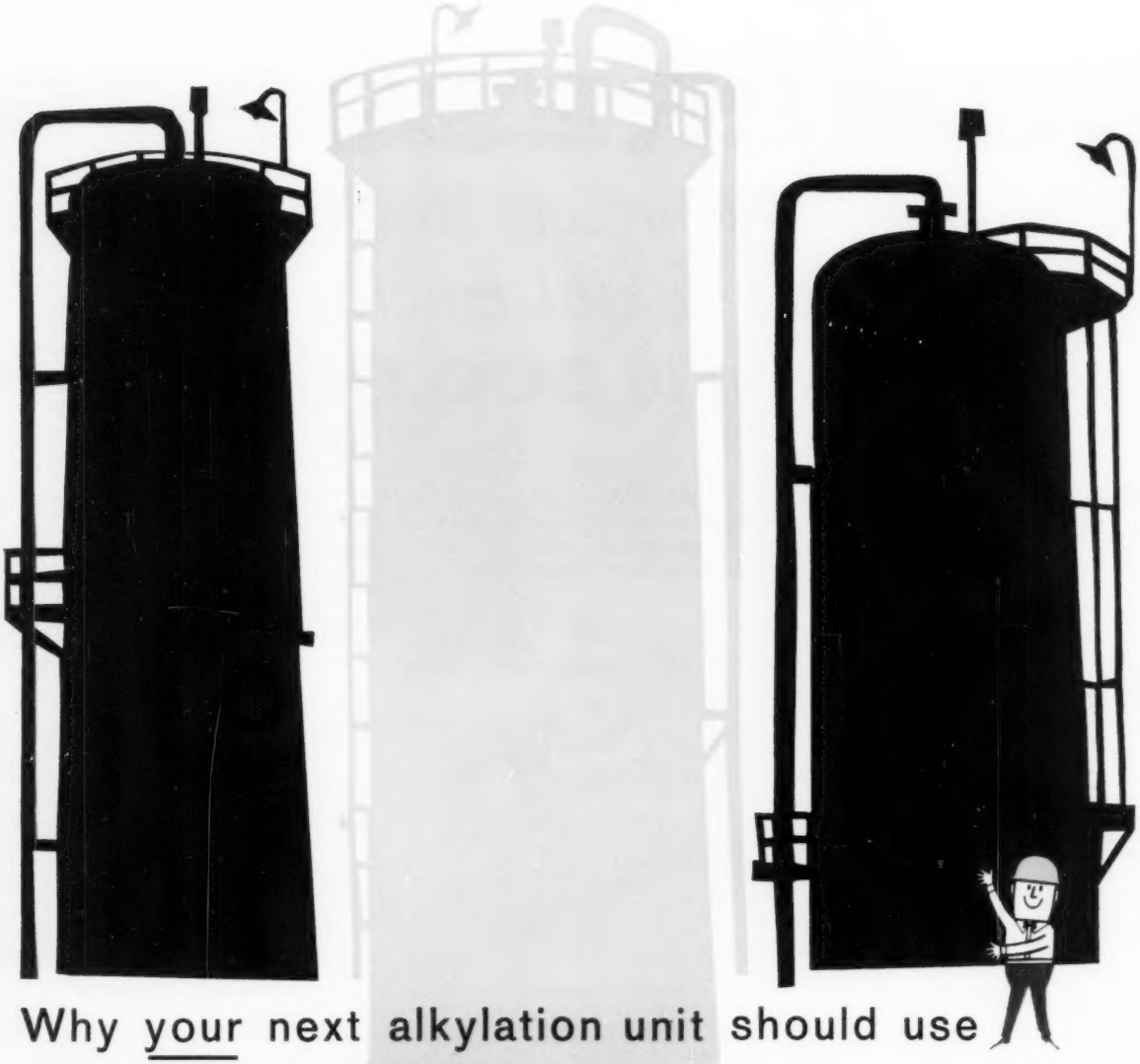
48 STANDARD FRAME SIZES

The total of 48 frame sizes permits accurate application for all compressor problems over the entire range of 500 cfm to 600,000 cfm. Pressures and speeds can be selected to meet the characteristics of the application, and the gas to be handled. *For further information, write Compressor Department, Jeannette, Penna.*

ELLIOTT THE MOST COMPLETE LINE OF **INTEGRATED COMPRESSOR & DRIVER UNITS** 500 cfm to 600,000 cfm

ELLIOTT Company
Jeannette, Penna.

PO-1



Why your next alkylation unit should use

HYDROFLUORIC ACID

Because anhydrous hydrofluoric acid is easily regenerated, you'll consume less catalyst per barrel of alkylate, lower your catalyst inventory and minimize spent acid problems. AHF lets you cool with water, reduces both initial and operating expense for cooling. And in addition to these economies, AHF gives you shorter reaction time and catalyst settling time, with minimum side reaction products. These advantages have been proved in operating alkylation units across the nation.

To help you cash in on AHF, Pennsalt provides expert, experienced technical aid. We'll show you how to handle, store and use AHF safely and economically . . . advise you on piping, pumps, valves and materials of construction . . . help you with employee training programs. See your Pennsalt representative or write for full information. Industrial Chemicals Division, PENNSALT CHEMICALS CORPORATION, Three Penn Center, Philadelphia 2, Pa.

Get this new HF handling and data book. Write on your letterhead for Bulletin S-148.

Pennsalt Chemicals
ESTABLISHED 1850

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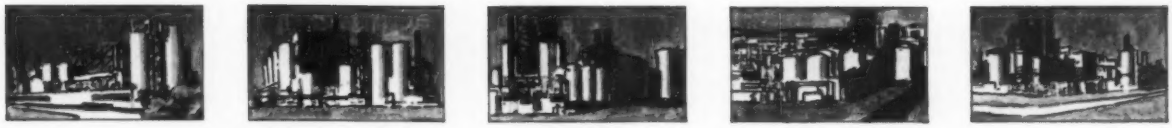
INDUSTRIAL QUÍMICA PENNSALT, MEXICO CITY



"GOOD TO SEE YOU AGAIN!"

We are always doubly gratified when a client asks us back to go to work on another project for him.

FIRST—We like the business.

SECOND—We interpret the invitation as an endorsement of our previous performance.

Repeat business is good for all concerned—it means the buyer and the seller are both pleased.

Individual clients have rewarded us with many repeat contracts. We would like to strike up a permanent friendship with you.

CATALYTIC · ENGINEERS · CONSTRUCTORS

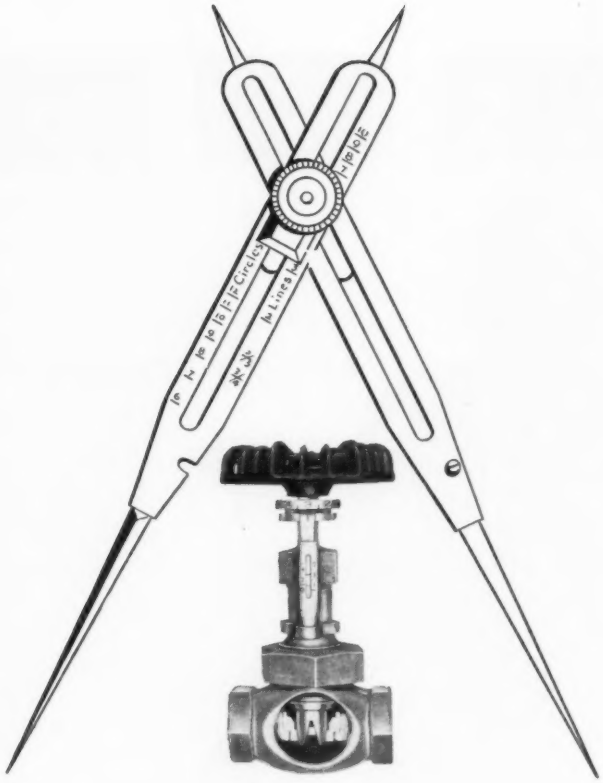
CATALYTIC

CONSTRUCTION COMPANY

PHILADELPHIA 2, PENNSYLVANIA

In Canada: Catalytic Construction of Canada, Limited; Sarnia, Ontario

For more data on advertised products, use Readers' Service Cards, last page.



PROPORTIONER

controls flow to save for you

The V-port disc in all Hancock "Flocontrol" Valves insures proportional flow throughout the entire lift of the stem. They are valves that help you achieve uniform product quality through closer control, save steam and fuel on process work, and cut maintenance costs.

"3 in 1" valve design combines variable orifice with shut-off and micrometer dial and pointer. The valve opening can be set within 1/10 turn of the handwheel —you can duplicate all settings easily, instantly. No shut-off valve required—flow is in a straight line, with separate shut-off seating surface located away from the V-ports.

Hancock "Flocontrol" Valves are available in Bronze and Steel to meet the most demanding services. Ask your industrial supply distributor for details.

Hancock "Flocontrol" valves assure positive pinpoint control—eliminate all guesswork.

MANNING MAXWELL & MOORE INC. TRADE MARK

HI-58

HANCOCK "FLOCONTROL" VALVES

A product of

MANNING, MAXWELL & MOORE, INC.

Valve Division • Watertown, Massachusetts
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

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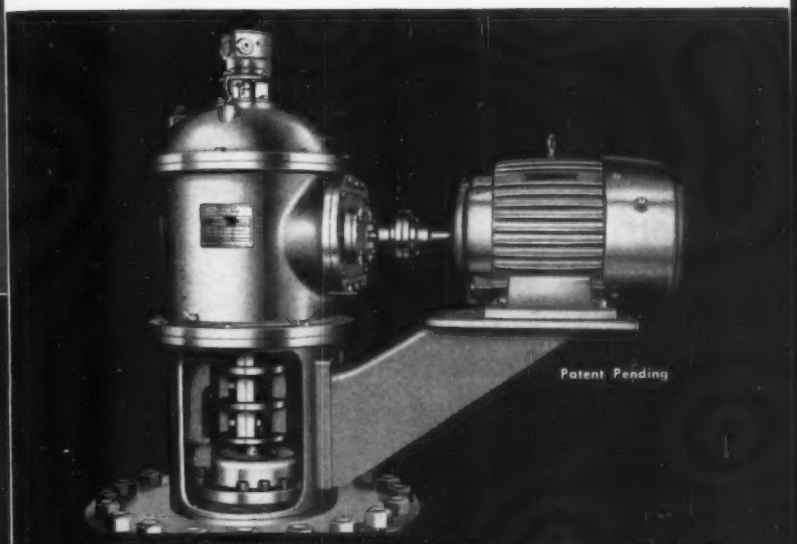
CUT MIXER MAINTENANCE COST

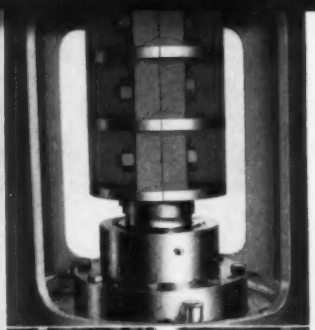
NEW NETTCO MECHANICAL SEAL CHANGE ELIMINATES COSTLY DOWNTIME



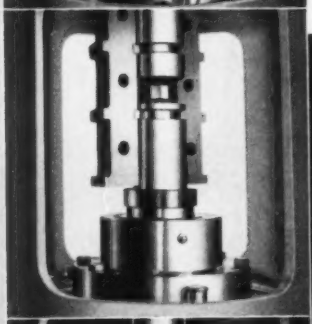
Improved Processing Through Engineered Agitation

SIMPLY DO THIS!

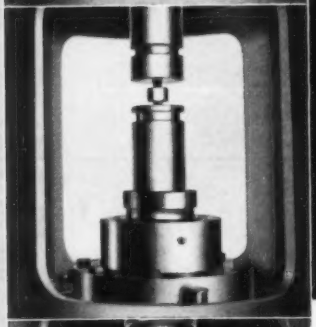
One easily assembled, self-aligning split sleeve coupling connects drive shaft and stirrer shaft.



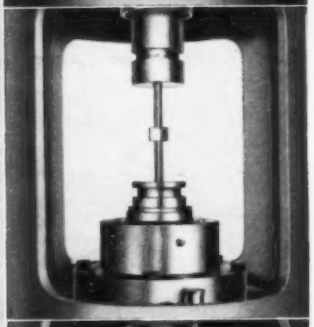
❶ Release sleeve collar set screws. Remove ½ of split sleeve coupling.



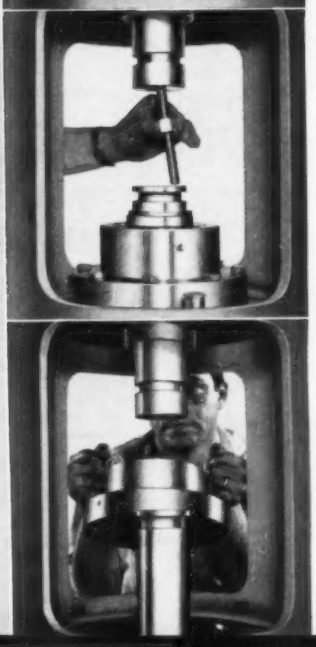
❷ Relieve shaft weight and remove remaining coupling half.



❸ Lower shaft on to support.



❹ Remove adjusting screw from opening.



❺ Unbolt and remove seal assembly. Reverse procedure to replace seal!

A few turns of a wrench . . . and Nettco seal assemblies on tank top mixers can be changed quickly, efficiently . . . regardless of mixer size. Costly downtime eliminated! Design simplicity reduces initial cost! No special skills or equipment required!

DESIGN FEATURES

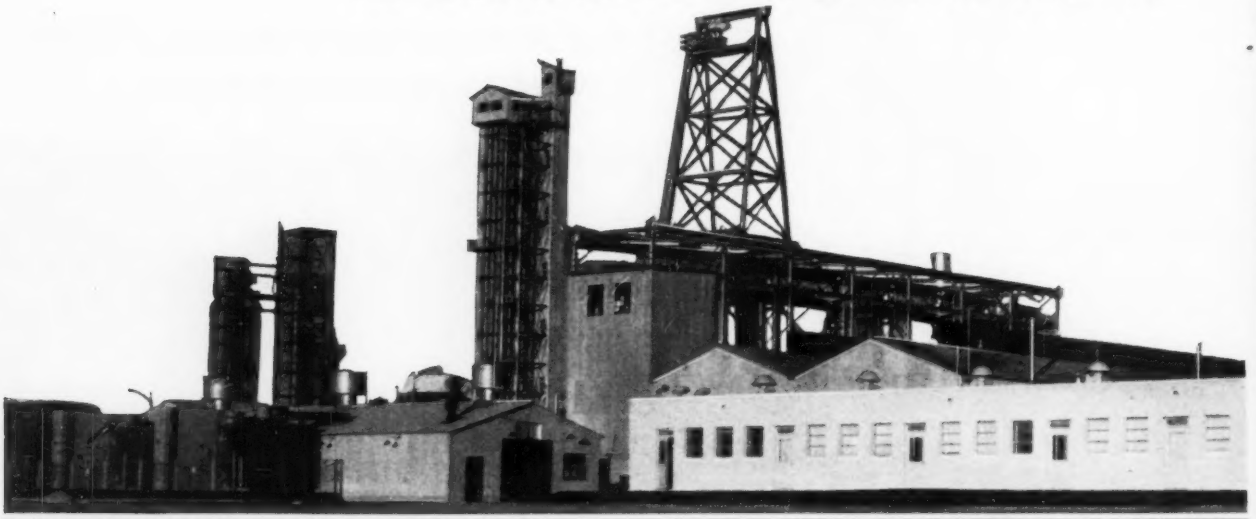
- No overhead lifting device required. Result: minimum overhead space needed . . . reduced maintenance labor and less downtime.
- Compact design with minimum distance between seals and drive bearings. Result: less shaft flexing at seals . . . reduced seal wear.
- Coupling jacks eliminated. Result: no working in cramped areas.
- No dismantling mixer . . . drive bearing untouched. Result: easier, faster seal maintenance . . . no bearing readjustment problems.

Nettco's Seal Replacement is easiest ever. For complete details, write for Bulletin 601 on your company letterhead. **Nettco Corporation, 81 Tileston St., Everett 49, Mass.**

NETTCO

ENGINEERED AGITATION SPECIALISTS
EVERETT 49, MASSACHUSETTS

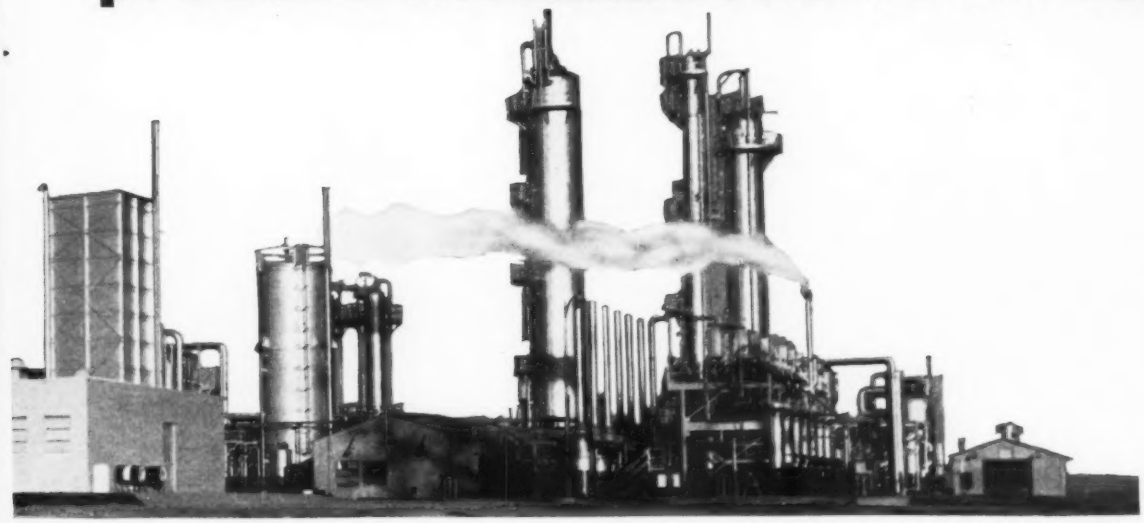
AMMONIA



FEED	NO. OF PLANTS	HYDROGEN PRODUCTION	NITROGEN SUPPLY	AMMONIA SYNTHESIS PROCESS	CAP. T/D	Location
BY-PRODUCT HYDROGEN	1	Oxygen Removal; NaOH Scrubber	Air Separation; N_2; O_2; Air	Casale	60	Michigan
ACETYLENE PLANT TAIL GAS	1	H_2O; Shift Conversion; CO_2 Removal; Liquid Nitrogen Wash	Air Separation; N_2; O_2; Air	Casale	110	Texas
HYDROGEN-RICH REFINERY OFF-GAS	2	H_2S Removal; CO_2 Removal; Low-temperature Fractionation and Liquid Nitrogen Wash; N_2	Air Separation; N_2; O_2; Air	2 Casale	380 180	Louisiana Illinois
NATURAL GAS (a)	5	O_2; Texaco Partial Oxidation; H_2O; Shift Conversion; CO_2 Removal; Liquid Nitrogen Wash; O_2; N_2	Air Separation; N_2; O_2; Air	4 Casale 1 Other	210 (b) 230 300 180 100	Mississippi Oklahoma Tennessee Kansas Brazil
OIL	2	O_2; Stm; Texaco Partial Oxidation; H_2O; Carbon Removal; H_2O; Shift Conversion; CO_2 Removal; Liquid Nitrogen Wash; O_2; N_2	Air Separation; N_2; O_2; Air	2 Others	110 (b) 120 (b)	Japan Japan
OIL (HIGH SULFUR)	2	O_2; Stm; Texaco Partial Oxidation; H_2O; Carbon Removal; H_2O; Sulfur Removal; Shift Conversion; CO_2 Removal; Liquid Nitrogen Wash	Air Separation; N_2; O_2; Air	1 Other	360 (b) 330	Spain Italy
NATURAL GAS	2	Steam; Air; H_2O; H_2S Removal; Steam Reforming; 1st Stage Shift Conversion; CO_2 Removal; H_2O; 2nd Stage Shift Conversion; CO_2 Removal; Methanation	From Secondary Reforming	2 Casale	200 115	Indonesia Iran
TOTAL	15	(a) Purification before oxidation not normally required. (b) Synthesis gas			2985	

For more data on advertised products, use Readers' Service Cards, last page.

process installations 1945-1960



Worldwide experience with six feeds utilizing seven process sequences to produce ammonia

More than one million tons per year ammonia capacity has been built or is under contract by Foster Wheeler. Eight Foster Wheeler plants account for 20% of the tremendous increase in the production of ammonia in the United States over the last decade. The table at left provides a brief view of FW's process flexibility and worldwide experience.

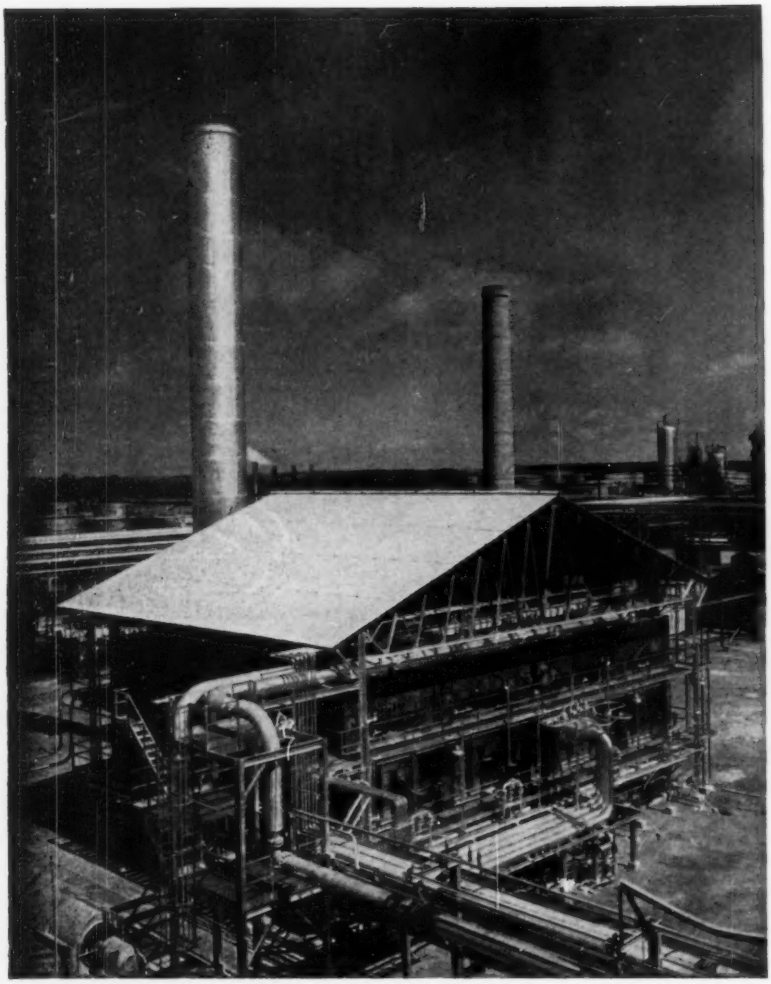
The most recently completed FW ammonia plant exceeded rated capacity within one month of start-up. Economic production over a wide range of outputs has been realized. From plants of modest size, to those in the higher capacity ranges, these Foster Wheeler ammonia plants turn in exceptional performances.

Foster Wheeler has also designed and constructed two of the largest urea plants in the United States. Both use the Pechiney-Grace process featuring total recycle and produce urea of superior quality and color. To get information on the ways Foster Wheeler process experience can serve you, write to Foster Wheeler Corporation, 666 Fifth Avenue, New York 19, New York.

Heat Engineered products, plants and processes... for the world's industrial progress.

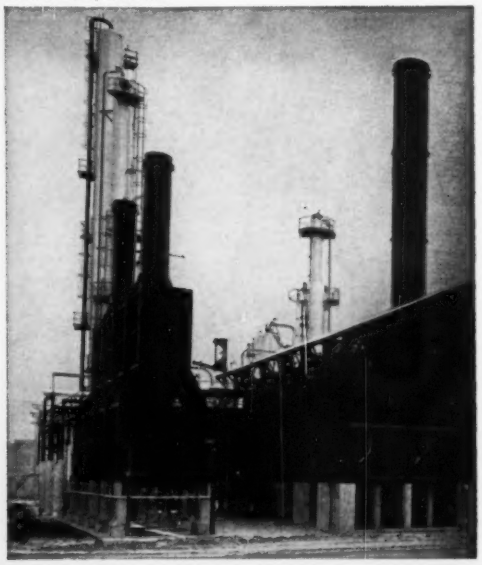
FOSTER FW WHEELER

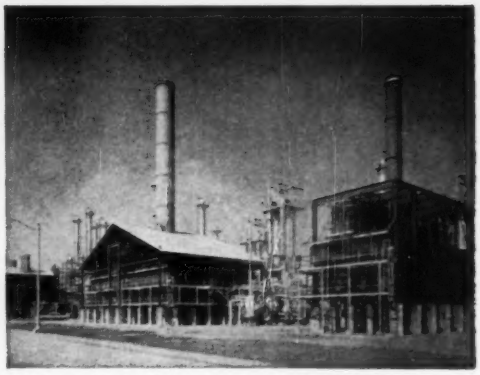
NEW YORK LONDON PARIS ST. CATHARINES, ONT.



Portable crude heater for Magnolia Petroleum Company, Beaumont, Texas.

Ultraformer heater for American Oil Co. at El Dorado, Arkansas.





Platformer and desulphurizer heaters for Shell Oil Co. at Deer Park, Houston, Texas.

HIGHER EFFICIENCY, LUMMUS OIL HEATERS

Lummus designs horizontal and vertical-tube oil heaters to any size, for any process—anywhere in the world

Major refiners confidently turn to Lummus on their important and difficult oil heater jobs.

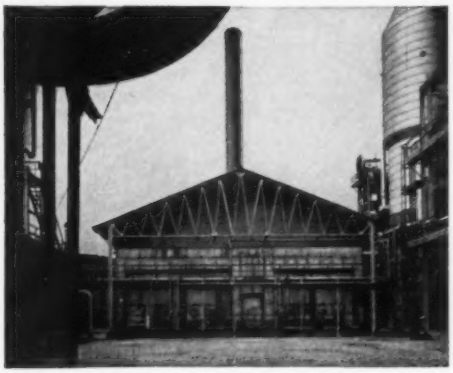
In the last 25 years, the combined capacity of all Lummus oil heaters built has exceeded that of any other company in the world. The reasons: greater durability, more efficient operation, an absolute minimum of days lost to downtime.

Major refiners maintain large engineering and economics staffs who can evaluate the performance of important heating equipment. They buy more Lummus oil heaters because they *know* through statistical comparison that Lummus gives them *more heater per dollar.*

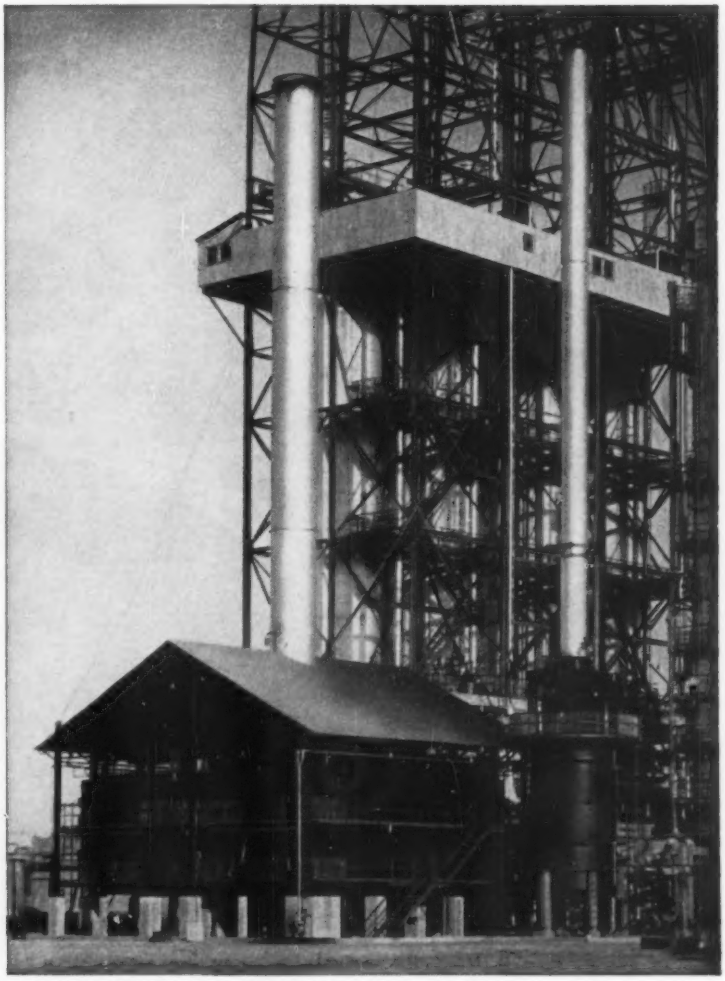
Lummus offers over a quarter of a century of oil heater experience for petroleum refineries, chemical and petrochemical plants. The highly trained engineering staff of the Oil Heater Division is ready in the Lummus New York office to give each job the full benefit of its accumulated know-how in this field.

Lummus oil heaters, of both special and standard design, range from 100,000 to 300,000,000 Btu per hour. As illustrated above, neither size, type nor location of the unit presents a problem to Lummus. Because Lummus offers *every* type of oil heater, you can be sure that we will recommend the *right*

For more data on advertised products, use Readers' Service Cards, last page.



Crude heater for Socony Mobil at Paulsboro, N. J.



Delayed coker heater for the American Oil Co. at Yorktown, Virginia.

MINIMUM DOWNTIME MAKE PREFERRED AMONG MAJOR REFINERS

unit for your needs. Complete Lummus facilities are available world-wide through any of the five international Lummus companies. Equipment is designed in New York, procurement is made through the nearest Lummus international office, and the cost of the job is payable in the currency of the country in which the procurement is handled!

Consult with Lummus on your next oil heater – large or small.

LUMMUS

THE LUMMUS COMPANY, OIL HEATER DIVISION
385 MADISON AVENUE, NEW YORK 17, N. Y.

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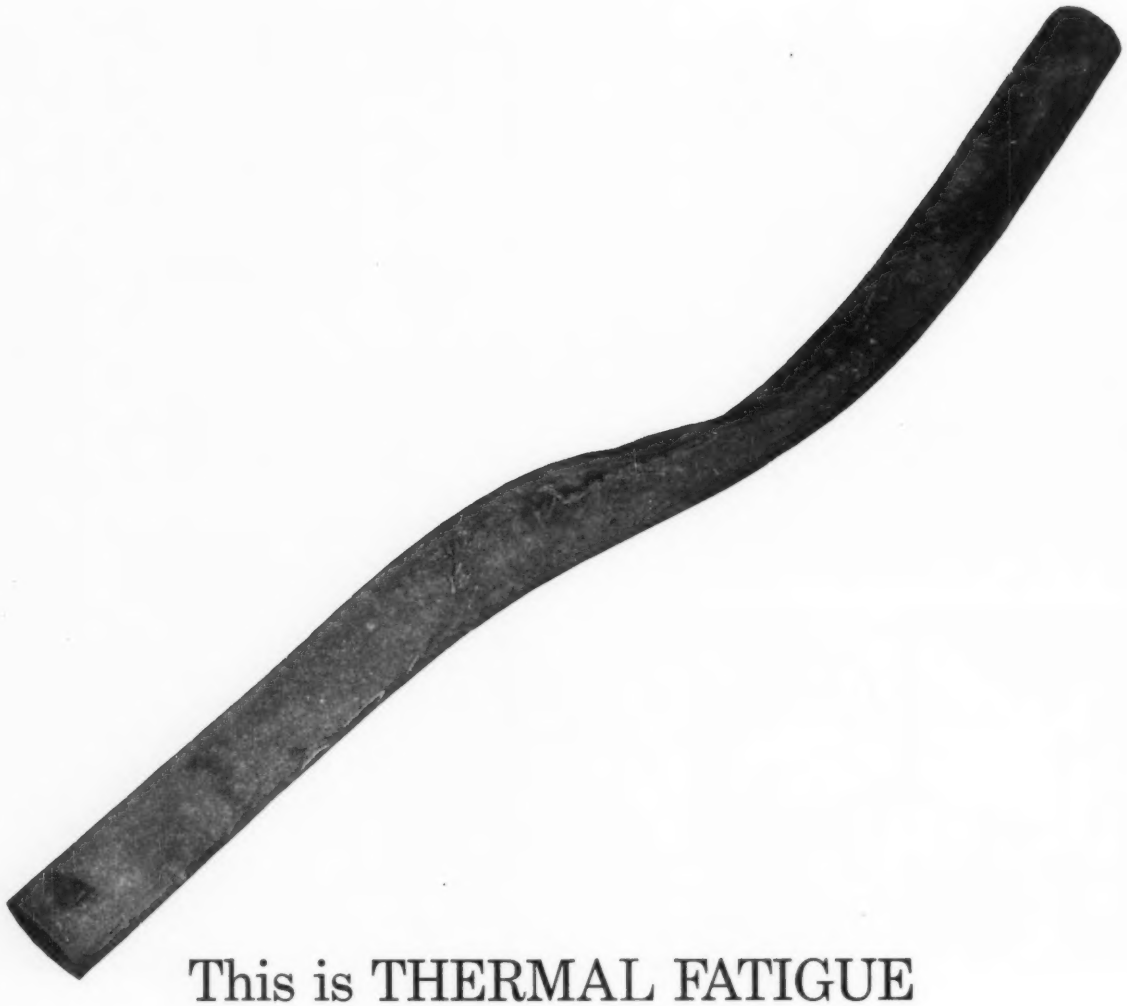

This is THERMAL FATIGUE

This photograph shows a heat-resistant furnace tube after thermal fatigue failure.

Thermal fatigue failure begins with cyclical temperatures and variable heat inputs. These conditions produce nonuniform thermal expansions and contractions. As a result, strong, hindered expansion and contraction stresses develop. These stresses produce plastic flow which results in the tube deformation shown above. Deformation of this type curtails furnace operations and constitutes thermal fatigue failure. Progressive deformation or severe thermal fatigue stresses will cause tube-rupture failures.

Thermal fatigue is an inherent problem in heat-resistant components, cast or wrought. As such, it occupies an important place in Electro-Alloys research efforts to lengthen life of components working under high temperatures and severe cyclical conditions.

We have created apparatus that assesses and analyzes the variables of thermal fatigue. Check with your Electro-Alloys representative for the meaning of our thermal fatigue data as it pertains to the material specification, design and service conditions of your heat-resistant components.

Send for free technical booklet on Thermal Fatigue

Please send me free copy of "The Mechanism of Thermal Fatigue," by Howard S. Avery—comprehensive report based on extensive lab studies:

Name_____

Title_____

Company_____

Address_____

City_____ State_____

Electro-Alloys, 20211 Taylor St., Elyria, Ohio

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION • Elyria, Ohio

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No fingerprints allowed

To make sure you get the premium quality you pay for when you buy stainless steel pressure tubing, we give it the white glove treatment. Our inspectors actually wear white gloves while working on these tubes. It's typical of steps taken to assure excellent surface finish and high internal quality.

You're assured of highest value when you buy Timken® stainless steel pressure tubes because:

Special techniques, unique in the industry keep physical properties and chemical composition at maximum uniformity.

You can select from a wide variety of sizes and analyses of tubing—many available nowhere else—to suit your needs.

You can call on the services of acknowledged experts in the field of stainless steel pressure tubing.

Call in Timken Company metallurgists to get the most for your money. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.

TIMKEN®
***Fine Alloy* STEEL**

TIMKEN ALLOY STEEL AND SEAMLESS STEEL TUBING ARE AVAILABLE FROM STEEL SERVICE CENTERS IN 44 CITIES IN THE UNITED STATES

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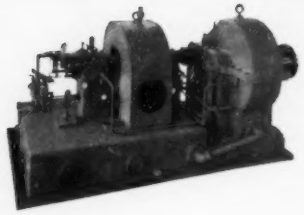
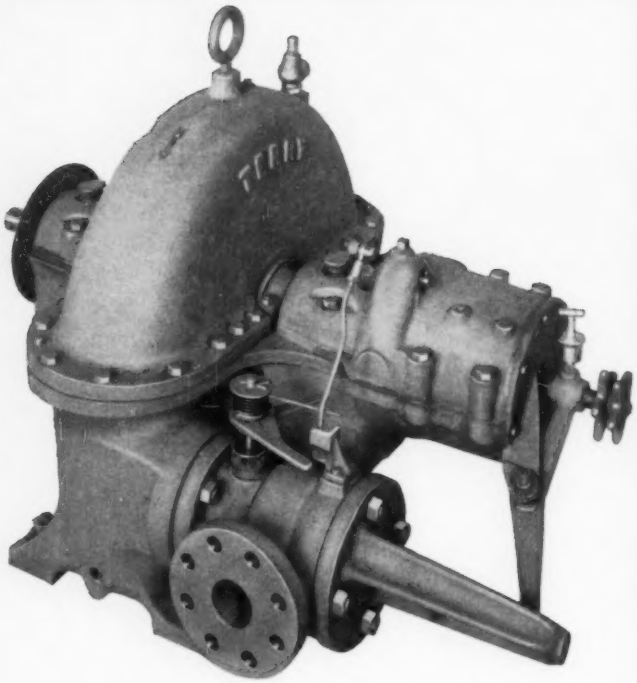
There's a Terry solid-wheel turbine for any mechanical-drive requirement



Solid-wheel turbo-geared unit rated 600 hp, 4000/650 rpm.



Standard solid-wheel turbine with constant-speed mechanical-type governor and hand speed changer.

The completeness of the Terry line of solid-wheel turbines enables you to choose an *ideal* drive for any application . . . choose the specific features you want from a wide variety of designs.

Standard turbines are made in capacities up to 2,500 hp, with either cast-iron or cast-steel casings. The standard wheel is carbon steel. Where operation is to be at high speed or at high temperature, wheels of forged alloy steel are used. Vertical and geared turbines are also available.

And you can select from a range of governors, including: constant speed, either mechanical or oil relay, and variable speed, either direct acting or oil relay. Excess-pressure or constant-pressure pump governors are also available. When required, remote speed control can be furnished for variable-speed governors.

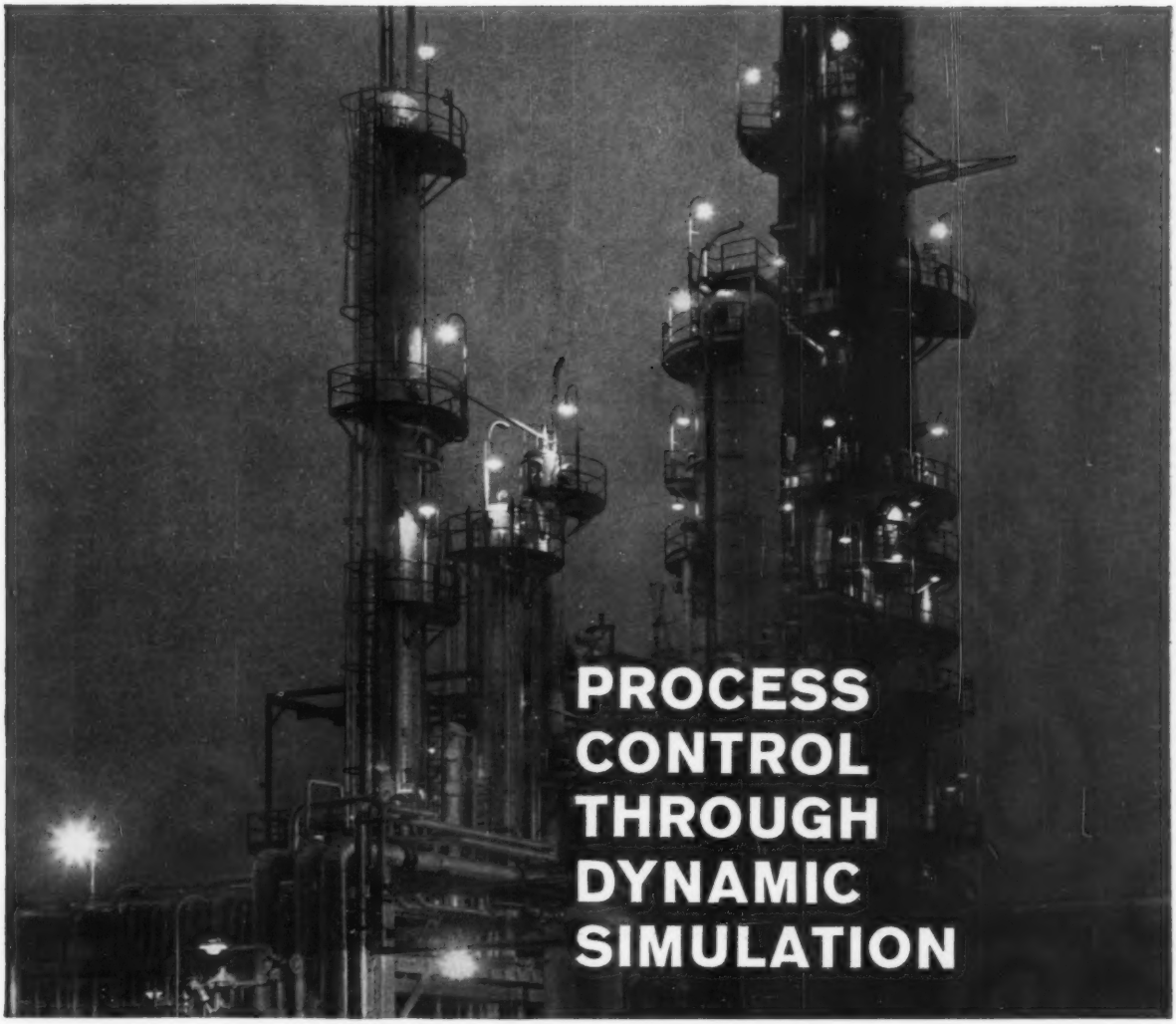
Tell us what your requirements are so we can send you full details of a turbine to meet your needs exactly. For general information, send for a copy of bulletin S-116.

THE TERRY STEAM TURBINE COMPANY
TERRY SQUARE, HARTFORD 1, CONN.

TERRY

Vertical turbines with the Terry solid wheel are available in capacities from 5 to 300 hp.

TT-1218



a new approach to process computer control

Through **dynamic simulation**, Link offers you process computer control that . . .

- **permits** dynamic study of transients during process upsets or load changes.
- **operates** on inputs/outputs familiar to process engineers and operators.
- **provides** a convenient engineering tool for studying operating procedures and process revisions.
- **is designed** to represent complete process needs without simplifying process or providing excess computer capacity.
- **can be** installed with minimum revision to existing instrumentation.
- **utilizes** standard analog and digital building blocks functionally grouped to permit installation in stages.
- **allows** integration with other processes to increase the scope of computer control.

If you are looking for maximum return on a minimum capital investment, consider Link **dynamic simulation** for your computer process control. For specific details—or an engineering presentation—contact J. C. Croft, Manager, Industrial Control Products.

LINK DIVISION
Binghamton, New York

Another example of Link / Ability
GENERAL PRECISION, INC.
Other Divisions: GPL, Kearfott, Librascope.

For more data on advertised products, use Readers' Service Cards, last page.

Reporting more news from . . .

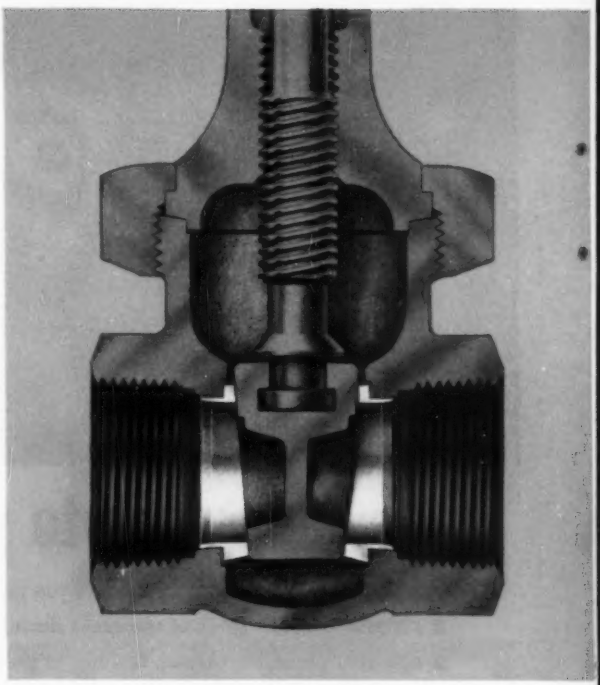
CRANE
DIRECTION '70

. . . a fast-moving program of planned expansion, product development, and streamlined distribution to help our customers meet the competitive challenges of the Sixties.

Only from Crane—this rugged bronze valve in a full range of pressure classes and sizes

Use these on your toughest services! Here are valves with a built-in safety factor that far exceeds minimum standards. Modern, cylindrical body design—the same as used on high-pressure steel valves—gives you extra protection against body distortion that causes leaks. Crane Exelloy seat rings defy operating wear and damage from foreign matter . . . drastically reduce your valve maintenance costs. And you get this extra performance at no more cost than you pay for a valve built to only minimum standards.

In addition to all these quality features, Crane gives you a far wider selection than any other comparable bronze valve line . . . a full range of sizes from ¼" to 3" . . . in both 200-pound and 300-pound pressure classes . . . in both rising stem and non-rising stem patterns. Your local Crane Distributor has these valves in stock and can ship your order without delay.



THANKS TO EXELLOY SEATS, ONLY THE REPLACEABLE DISC GETS THE WEAR

Crane Exelloy (12% chromium steel) seat rings, expanded into body, give a hard bearing surface with superior resistance to wear, indentation, or scoring. Normal seating wear is shifted to the easily replaceable bronze wedge disc. Ordinary bronze valves wear on both disc and seat, an expensive maintenance factor. But with this Crane bronze valve you need only slip in a new disc to get a like-new, tight-seating valve.

For more data on advertised products, use Readers' Service Cards, last page.

No. 424; 200 Pound
No. 634E; 300 Pound

"BEEFED-UP" BODY DEFIES DISTORTION TO MAINTAIN TIGHT SEAL

This Crane bronze gate valve has a cylindrical body . . . the best design to withstand internal pressures. Ordinary rectangular body design creates stress concentration at corners, which may result in distortion of the valve body causing leakage or early failure. Huskier, better integrated Crane design has more rigidity under strains, reinforces seats against wedging action of disc.

CRANE®

Crane Co., Industrial Products Group, 4100 S. Kedzie Ave., Chicago 32, Ill.

VALVES • ELECTRONIC CONTROLS • PIPING • PLUMBING • HEATING • AIR CONDITIONING

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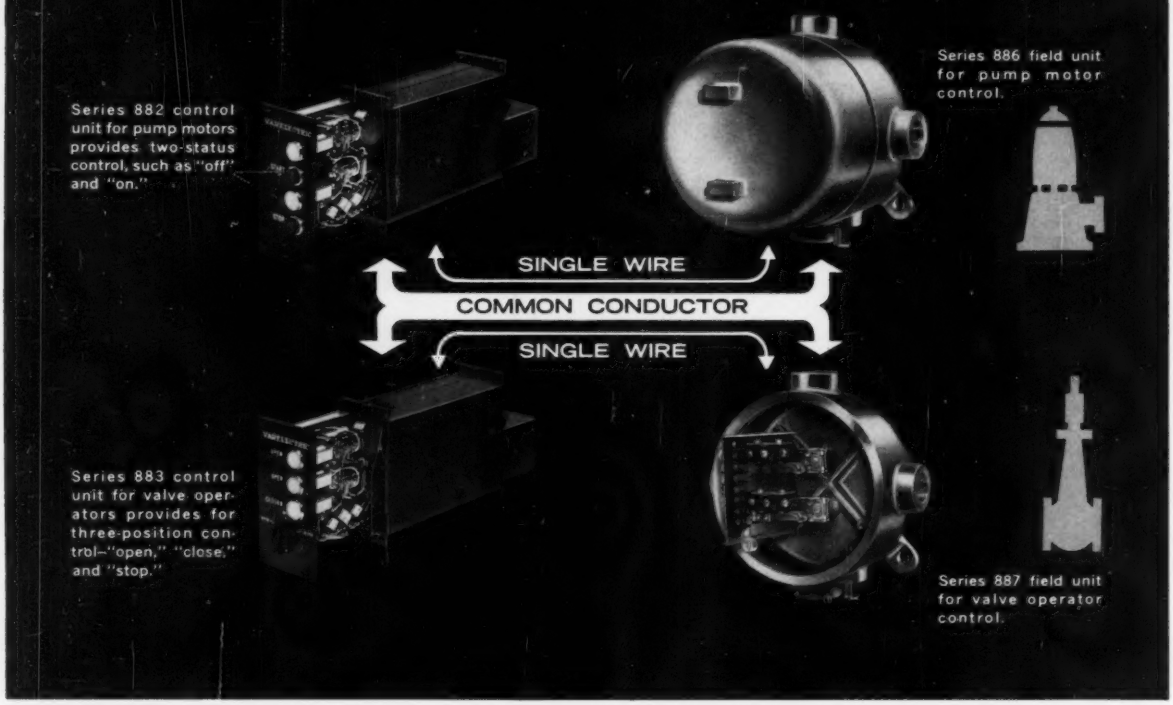
VAREC VARELECTRIC

NEW TWO-WIRE SUPERVISORY CONTROL OF PUMPS AND VALVES COSTS LESS AND PERFORMS BETTER THAN MULTI-WIRE SYSTEMS


Series 882 control unit for pump motors provides two-status control, such as "off" and "on."
Series 886 field unit for pump motor control.
SINGLE WIRE
COMMON CONDUCTOR
SINGLE WIRE
Series 883 control unit for valve operators provides for three-position control—"open," "close," and "stop."
Series 887 field unit for valve operator control.

The Varelectric 880 Series provides direct, instantaneous control of pump motors, valve operators and similar electrically-operated equipment, while continuously supervising and indicating the status of the controlled devices. Using only one wire between each field and control unit, *plus a common conductor for many units,* a Varelectric system can cut field wiring costs to as little as 25% to 15% of that of conventional systems—which often require from seven to nine wires between individual units.

VARELECTRIC offers these advantages:

- **ECONOMY:** Saves from 75% to 85% of field wiring costs...uses two wires instead of many.
- **RELIABILITY:** Uses continuous, well-filtered, direct current...no AC or DC pulsating current used.
- **PRECISION:** Uses the bridge circuit concept... inherently detects trouble.
- **FLEXIBILITY:** Modular construction provides for flexibility of application...dustproof case attaches to operator's control panel.
- **BROAD APPLICATION:** Varelectric systems can control any electrically-operated equipment up to three statuses.

For applications in the petroleum and chemical industries, or wherever control is vital, Varelectric furnishes the most modern, economical solution to control problems. For full details, send for Bulletin CP-3708. Write Dept. PR 1141-1.

"Varec"
TRADE ® MARK

THE VAPOR RECOVERY SYSTEMS COMPANY
2820 North Alameda Street • Compton, California

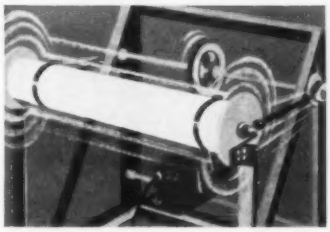
Branches and Representatives in Principal Cities.

TOUGH

NEW PIPE INSULATION

...deflection at breaking point 2 to 4 times that of ordinary insulation

You can almost forget about handling breakage with remarkable new "K&M" Zebra. As proved in tests by K&M and independent testing laboratories, Zebra won't crack or warp from shock or heat. It withstands intense vibration without cracking or abrading.



Zebra is made in half sections even for the larger pipe sizes . . . for faster application with fewer joints. Despite its rugged, full body, it's relatively lightweight . . . easy to cut and fabricate. It's a low, medium and high-temperature multi-layer sectional-type thermal insulation. And it meets your requirements for density, conductivity, modulus of rupture, and resistance to soaking heat. Write today for more information and a free sample of new "K&M" Zebra. It's tough, economical, fast to apply. That's Zebra . . . by K&M! Keasbey & Mattison Company, Ambler, Pa. Dept. I-2110.

In Canada: Atlas Asbestos Company Ltd., 5600 Hochelaga Street, Montreal 5, Canada.

• for temperatures of 200° F to 1200° F • smooth surface won't irritate or cut skin • made of calcium silicate-asbestos fiber bonded felts • can be re-used . . . dismantled and re-applied • practically dust-free • available in a wide range of sizes and thicknesses.

ZEBRA

K·M BEST IN ASBESTOS

Keasbey & Mattison at Ambler

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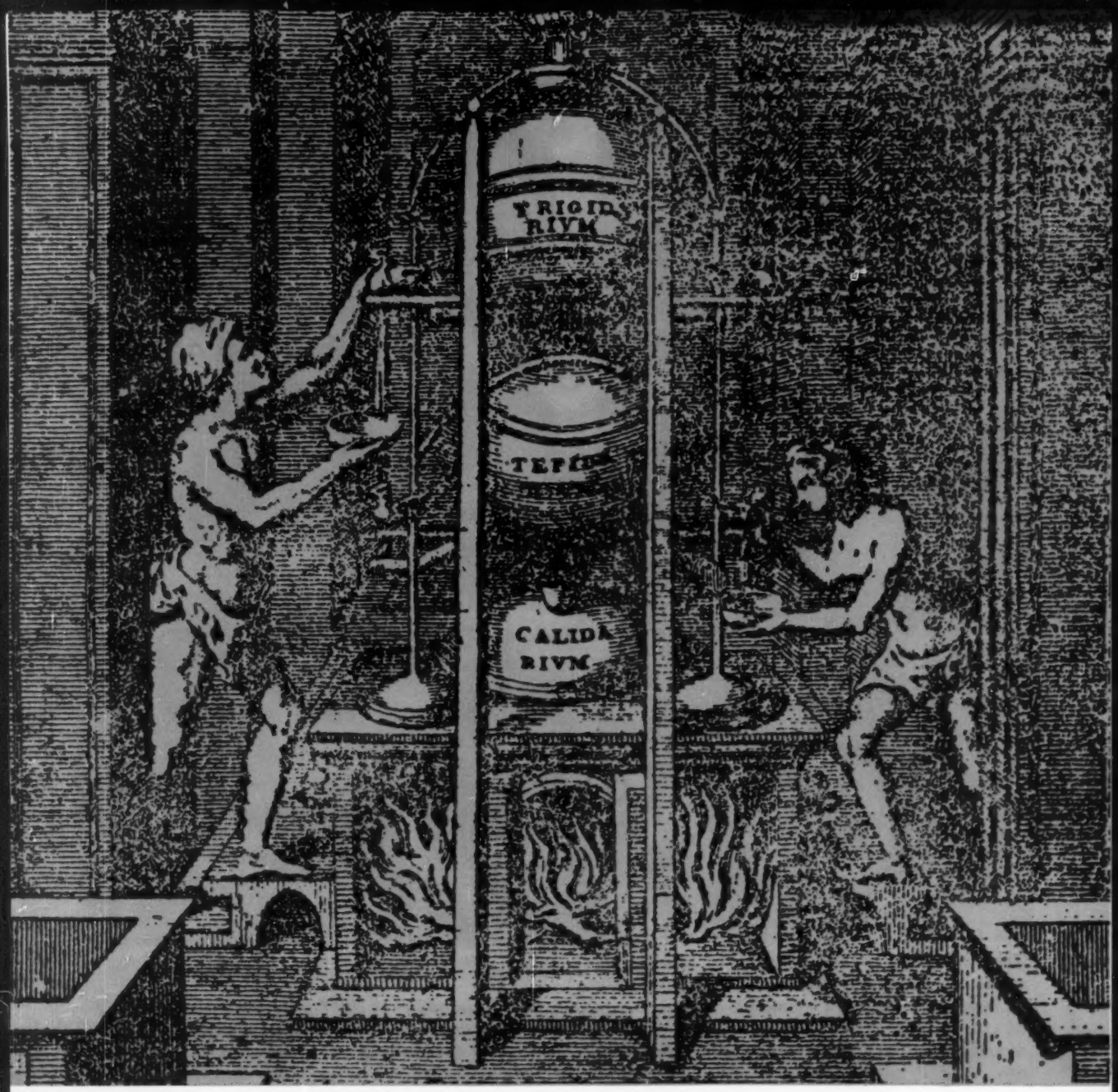
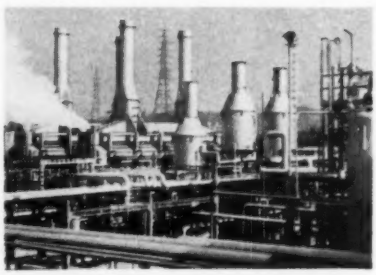


Where would we be without a still .....?

Without a still or two, many of us would find it dull, dry world. But vastly more important, without the huge, complicated stills that produce the myriad oil products essential for our modern life—for refineries are basically stills—it would be a different world indeed. For the past thirty years, the Japan Gasoline Company has designed and built some of the finest petroleum and petro-chemical plants in Japan. Be sure to consult our staff of experts in the field for all types of advice and assistance when building or enlarging your plant.

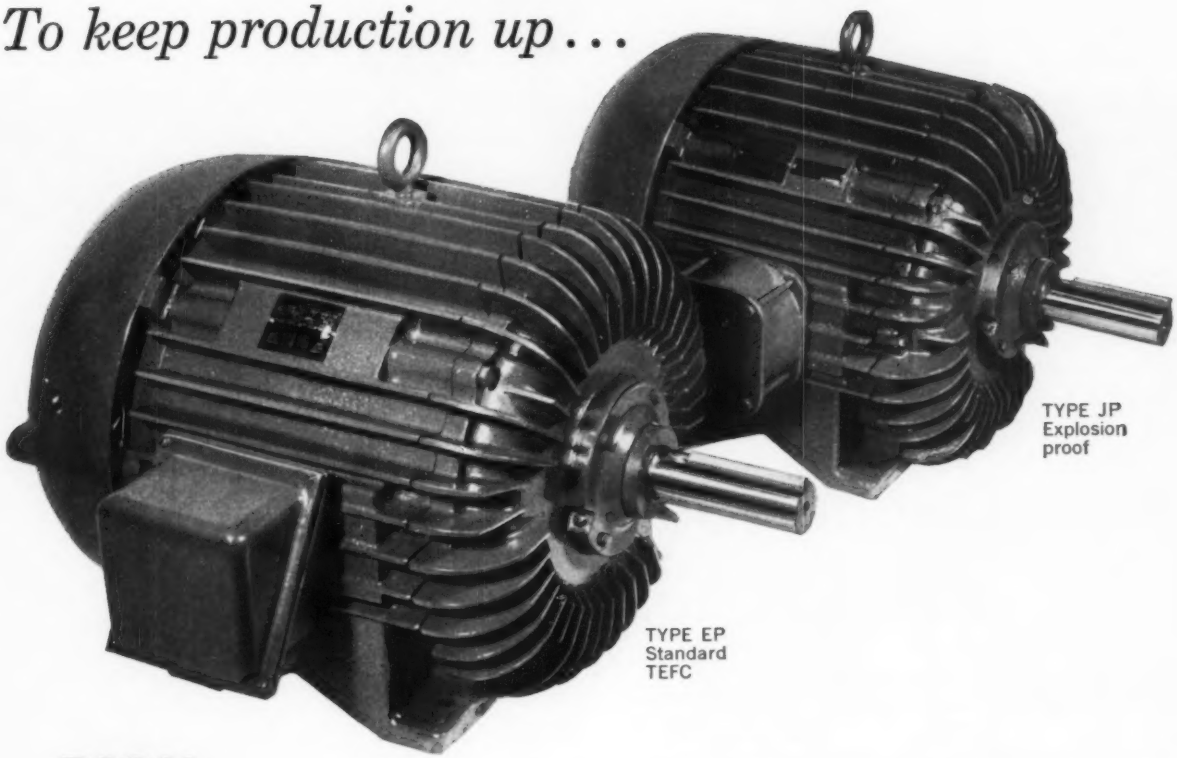


Engineers & Constructors

JAPAN GASOLINE CO., LTD.

New Otemachi Bldg., 2-4, Otemachi,
Chiyoda-ku, Tokyo, Japan.

To keep production up . . .



PICK FROM THIS PROTECTED PAIR...

Here's a power-packed pair of Wagner® totally-enclosed fan-cooled motors —Type EP, standard, protected against damage from dust, abrasive, fumes, steel chips or filings; and Type JP, explosion-proof, for safe use in specified hazardous locations.

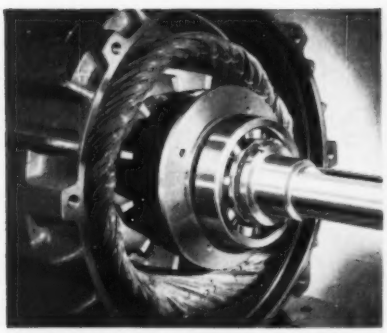
They'll keep your production rates up, delivering full rated horsepower under the toughest conditions . . . staying on the job with dependable, continuous service that means peak output. They're the perfect pick, for individual machines or for automated lines.

In the design illustrated, these motors are built in ratings through 100 hp in NEMA frame sizes 182-445U. Let your Wagner Sales Engineer show you how this protected pair (or larger Wagner enclosed motors through 500 hp) gets the job done. Call him, or write us for Bulletin MU-224.

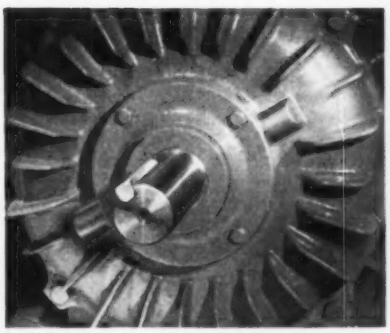
Wagner Electric Corporation

6458 PLYMOUTH AVENUE, ST. LOUIS 33, MISSOURI

WM60-19



HEAVY-DUTY BALL BEARINGS . . . The ball bearings used in these motors are of the highest quality, with more than ample capacity to provide long, troublefree service under heavy loads.

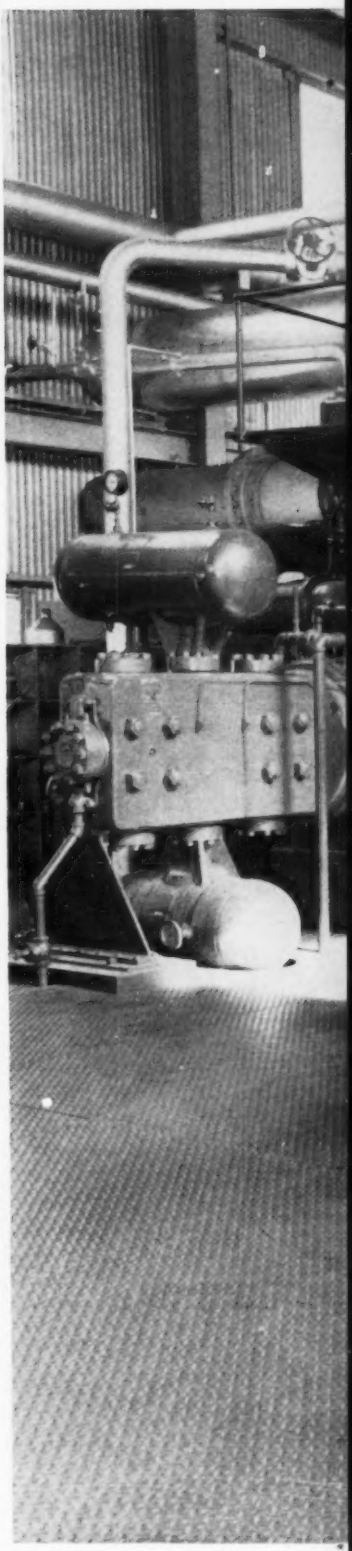


BEARINGS CAN BE RELUBRICATED . . . Factory lubrication will last for many years under normal service, but openings are provided to permit relubrication that adds years to motor life under severe conditions.

SECURELY SEALED FOR LOW MAINTENANCE . . . Both ends of these motors have running shaft seals to keep the bearings clean. Bearing housings are effectively sealed to prevent escape of grease.

For more data on advertised products, use Readers' Service Cards, last page.

Noel M. Champion *(left), Chief Engineer, Armour Agricultural Chemical Company, discusses a technical problem with* Robert L. Kietzman, *Sales Engineer, The Cooper-Bessemer Corporation, St. Louis District Office.*



How Cooper-Bessemer service helps keep the ammonia flowing

At Armour Agricultural Chemical Co., Crystal City, Missouri, nine Cooper-Bessemer compressors play key roles in the manufacture of ammonia products. Round the clock, for five years, these units have given exceptional performance under the rigors of such problems as handling pressures up to 9000 psi.

The performance of these C-B compressors has been backed by Cooper-Bessemer engineers in the St. Louis area and in Mt. Vernon, contributing helpful service for these high-pressure operations.

Cooper-Bessemer engineers will gladly help *you* plan compression facilities, and demonstrate how this unique service works for your benefit. Call the nearest office.

BRANCH OFFICES: Grove City • New York • Washington • Gloucester Pittsburgh • Detroit • Chicago • Minneapolis • St. Louis • Kansas City • Tulsa New Orleans • Shreveport • Houston • Greggton • Dallas • Odessa • Pampa Casper • Seattle • San Francisco • Los Angeles • *SUBSIDIARIES:* Cooper-Bessemer of Canada, Ltd.... Edmonton • Calgary • Toronto • Halifax Stratford • C-B Southern, Inc.... Houston • Cooper-Bessemer International Corp.... New York • Caracas • Anaco • Cooper-Bessemer, S.A.... Chur, Switzerland • The Hague, Netherlands • Mexico City • The Rotor Tool Company... Cleveland

Cooper Bessemer

GENERAL OFFICES: MOUNT VERNON, OHIO

ENGINES: GAS - DIESEL - GAS-DIESEL
COMPRESSORS: RECIPROCATING AND CENTRIFUGAL,
ENGINE, TURBINE OR MOTOR DRIVEN

Noel M. Champion *(left) and* Thomas H. Ferebee, *Supt. Ammonia Plant. In background are two GMWA-10, four GMWA-8 and one GMWA-6 engine driven compressors for compression of air, natural gas, synthesis gas and ammonia. Armour also has two FM compressors for ammonia recirculators.*

DE LAVAL

CENTRIFUGAL COMPRESSORS

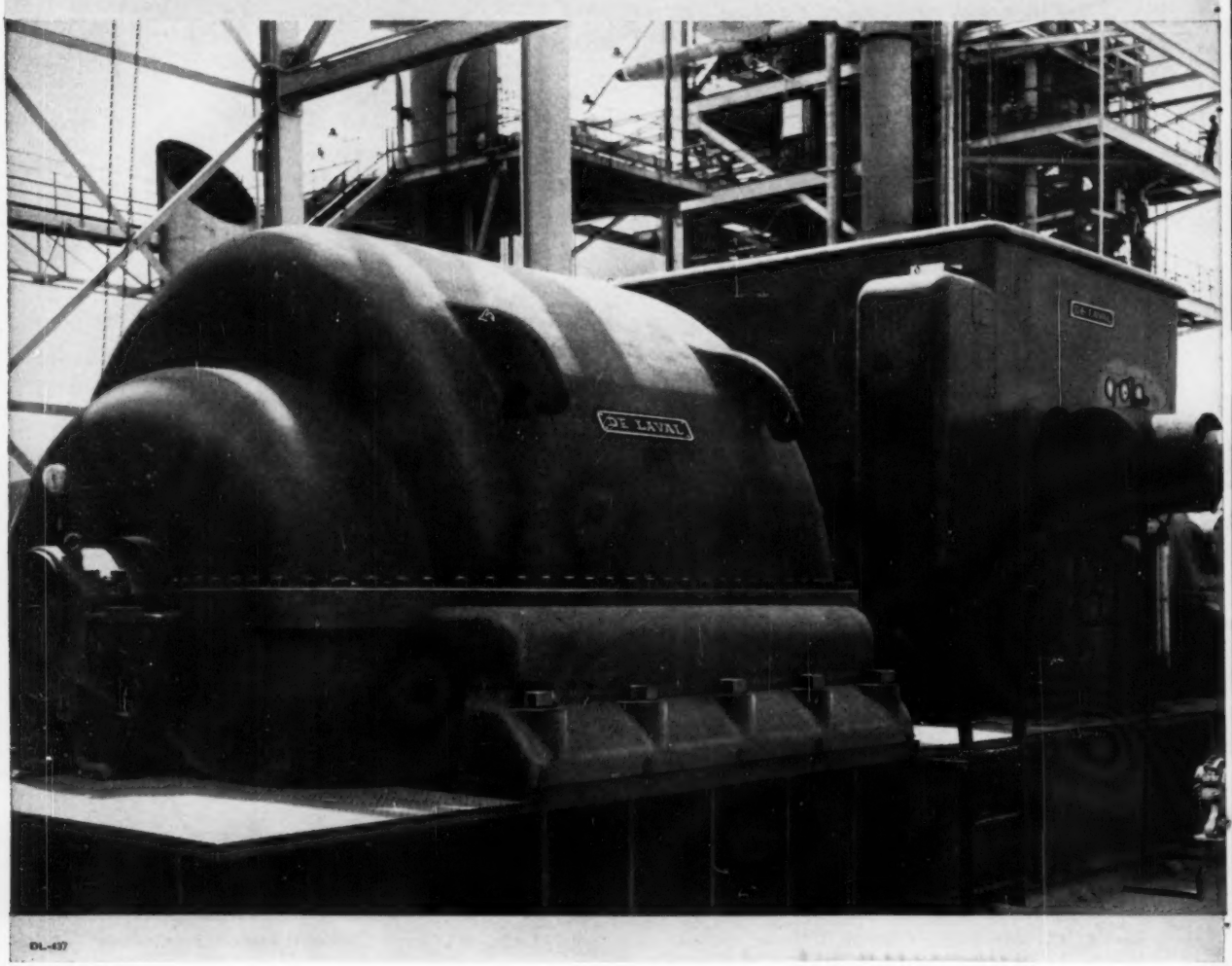
11,300

Driven by automatic extraction steam turbine

Shown below is the large 11,300 horsepower centrifugal blower which compresses air for the main blower service in catalyst regeneration at Standard Oil of Ohio's new refinery at Toledo, Ohio.

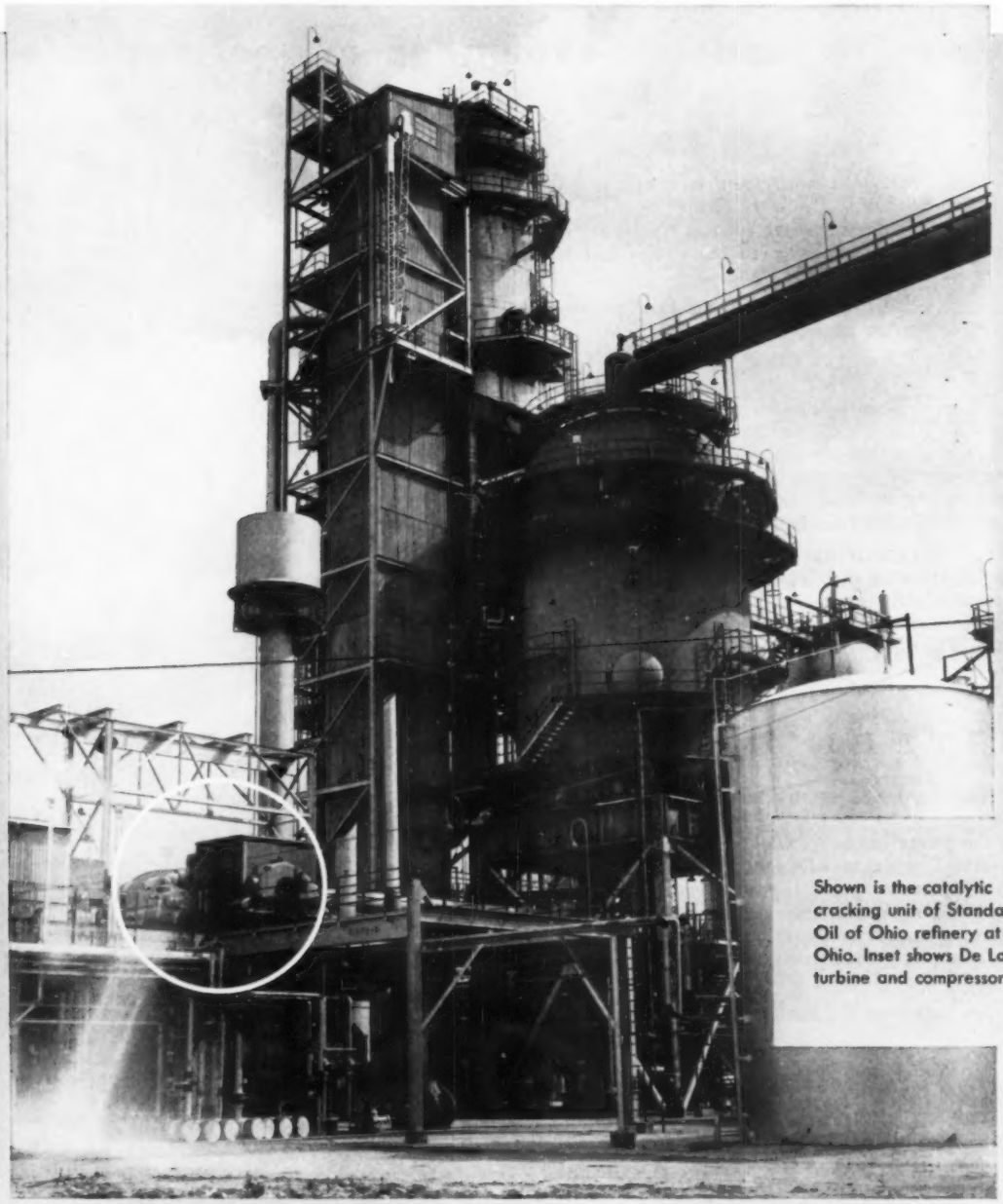
Driven by a De Laval single automatic extraction steam turbine, it compresses 110,300 cfm in four stages at 2800 rpm. Inlet pressure is 14.7 psia and discharge pressure is 40.7 psia. The turbine is designed for 600 psig ISP, 740F extracting at 55 psig, and exhausting to 28″ Hg.

This is another example of De Laval proved performance.



DL-437

horsepower DE LAVAL compressor for "cat cracker" at SOHIO refinery



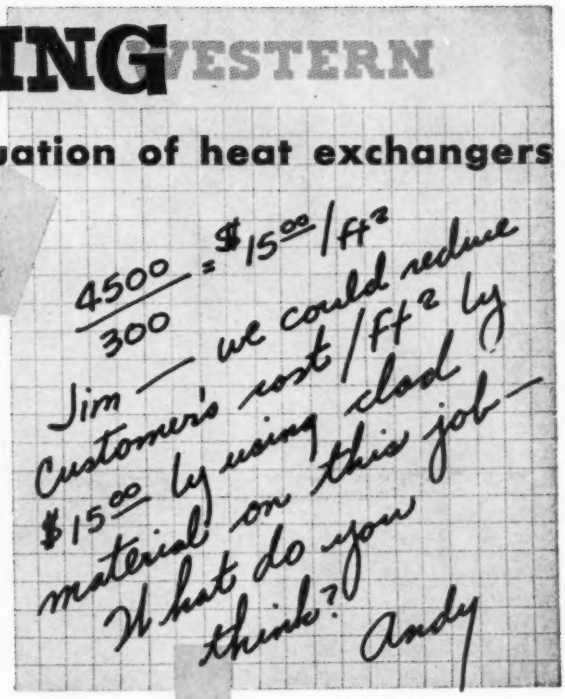
Shown is the catalytic cracking unit of Standard Oil of Ohio refinery at Toledo, Ohio. Inset shows De Laval turbine and compressor unit.

DE LAVAL *Steam Turbine Company*

811 NOTTINGHAM WAY, TRENTON 2, N. J.

COST ENGINEERING

is the key to economic evaluation of heat exchangers


WESTERN
4500/300 = $15.00/ft²
Jim — we could reduce Customer's cost/ft² by $15.00 by using clad material on this job — What do you think?
Andy

Recognizing the importance of accurate economic evaluation of capital equipment to our customers' profit structures, Western's engineers have for many years applied cost-engineering principles to the design and fabrication of all Western Heat Exchangers.

This has special significance in continuous flow processes, where operations never cease and where operational and maintenance economies often spell the difference between profit and loss.

With an intimate knowledge of heat transfer technology as well as process operating conditions, Western has often been able to aid in such evaluation and long-range economy by suggesting short-cuts and improvements, while yet maintaining the efficiency and quality for which Western Heat Exchangers have gained respect.

Western's engineering staff takes professional pride in the accuracy of their evaluations, and they can be of great benefit to your own cost engineers when heat transfer is a factor in your process developments. Why not put them to the test?

WESTERN'S STAKE IN YOUR FUTURE

. . . is in the young engineers who are interested in the specialty of "cost-engineering" in heat transfer economics. To stimulate such thought, another of Western's "personal-professional-advancement" messages, partially shown at right, currently appears in several trade journals. A more complete treatment of the subject is available in pamphlet form, singly or in quantity, upon request.

One of a series appearing in OIL & GAS JOURNAL, CHEMICAL ENGINEERING, PETROLEUM REFINER, REFINING ENGINEER, CHEMICAL ENGINEERING PROGRESS.

serving the growth of the process industry

WESTERN

HEAT EXCHANGERS

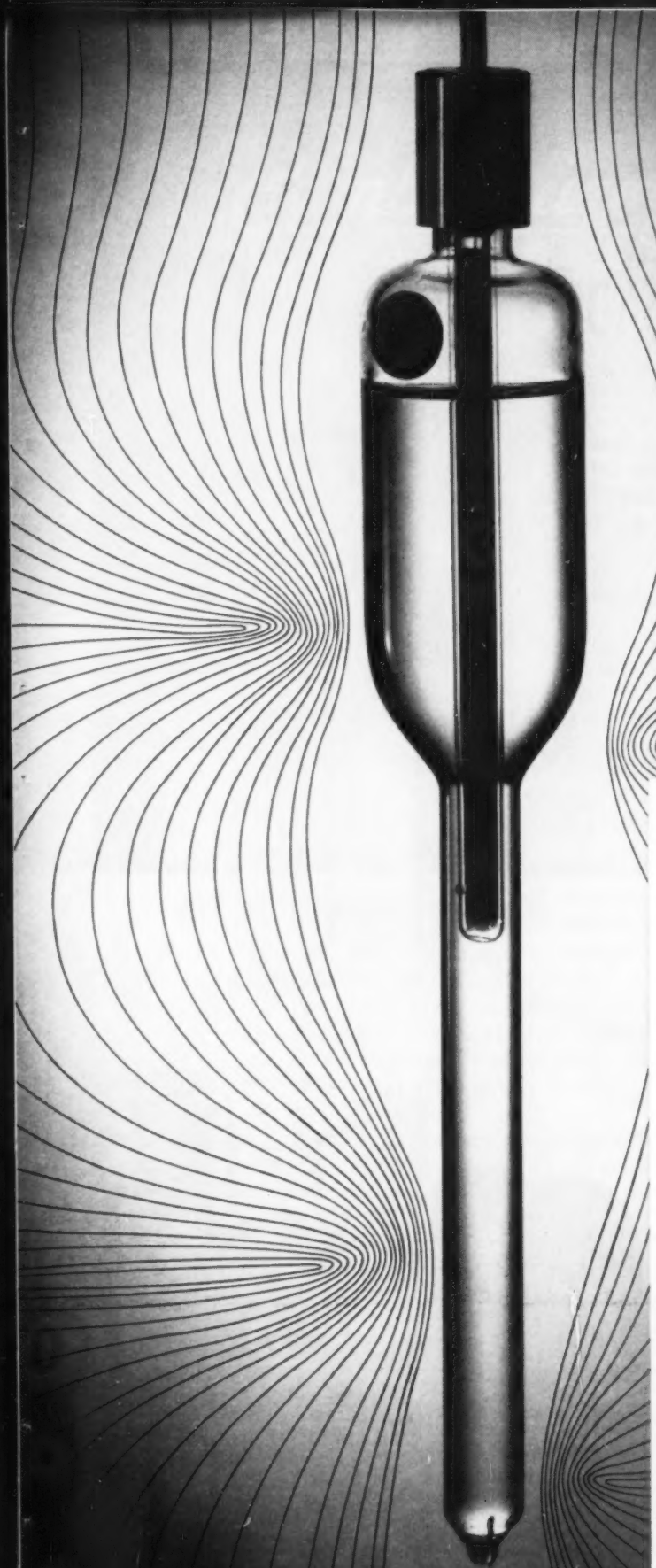
WESTERN SUPPLY COMPANY

P. O. Box 1888 — Tulsa, Oklahoma

Design Economics of Heat Exchangers Furnish Basis for Heat Transfer Cost Engineering

The application of cost engineering practices in the accurate evaluation of capital equipment in the process industry is rapidly becoming more and more vital to the management of process companies, as margins of profit grow narrower.

For more data on advertised products, use Readers' Service Cards, last page.



pH under pressure... high or low pressure, hydrostatic head... Beckman Reference Electrodes are the very heart of superior pH measuring systems *under pressure extremes.* ⌘ Pressurized reference electrodes open new areas of pH control... in process streams up to 100 psi ... at temperatures up to 212° F... where only hydrostatic pressure is required... for accurate measurements from 0 to 14 pH. A comprehensive line of mountings offers a variety of pH system installations. ⌘ Beckman pH accessories, meters and electrodes are available through leading recorder companies. For detailed information ask for Data File 25-11-06

Beckman
Scientific and Process Instruments Division

INSTRUMENTAL IN YOUR FUTURE 25 YEARS 1935-1960

Beckman Instruments, Inc.
2500 Fullerton Road,
Fullerton, California

It's a Fact: Three separate plug-in components in the Model W Industrial pH Meter allow easy, quick maintenance, even by untrained personnel.

From the wellhead through the refinery gate BRIDGEPORT TUBES HELP CARRY THE LOAD

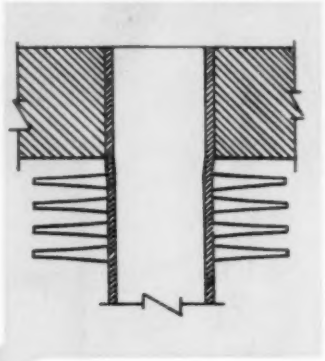
Right from the wellhead—Bridgeport is in the oil and gas production picture with aluminum, brass and copper base alloys in corrosion-resistant, single-wall and duplex tubes.

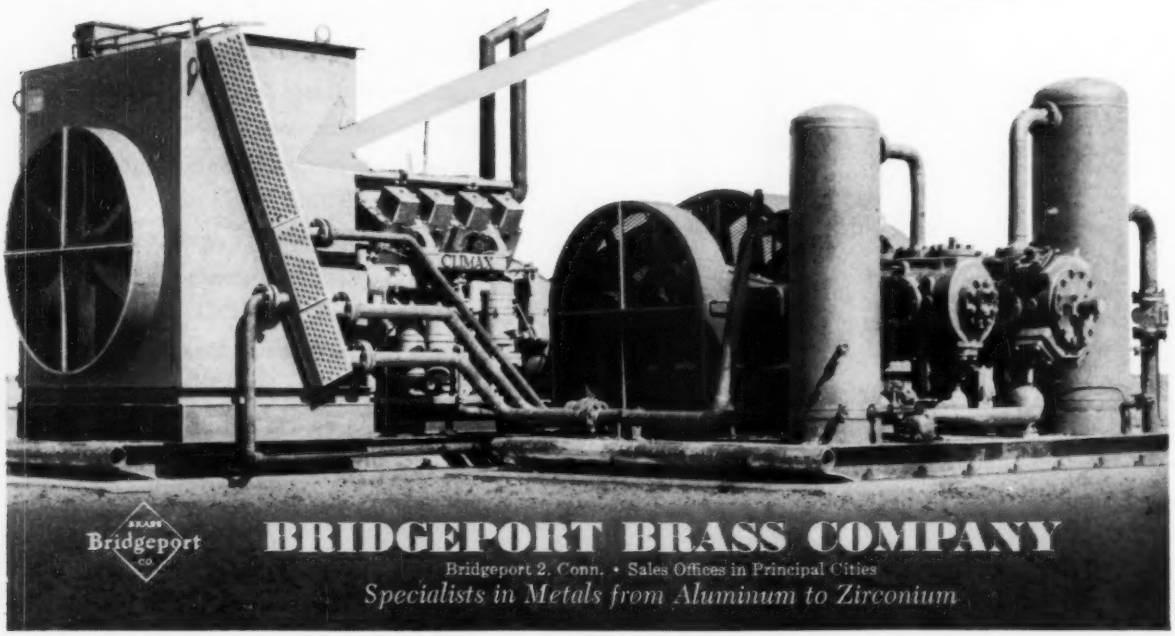
In natural gas production, for example, air-cooled heat exchangers at the wellhead do an around-the-clock job in both radiating the heat from the compressor engine and cooling the compressed gas before it is sent on its way to the gathering stations.

The air cooler illustrated here is manufactured by Air-X-Changers, Inc., Tulsa, Oklahoma. This model uses aluminum fins on Bridgeport Arsenical Admiralty condenser tubes. The tube bundles are mounted in a chamber, and fan-blown air across the finned surface cools either the compressor engine jacket water or the interstage and after-stage compressed gas. Bridgeport Inhibited Admiralty tubes are generally preferred for this type of service because of their corrosion resistance to both water and gas. And Bridgeport Aluminum Fin Stock is specially engineered for applications like this.

The range of Bridgeport condenser tube alloys—both single wall and duplex—is equaled by our vast experience in dealing with the special corrosive media encountered in the oil industry. This combination of quality products and technical engineering service pays you *all along the line.* Learn more about the benefits of Bridgeport Tubes and Technical Service for your applications. Write Dept. 5011.

Cross section of Air-X-Changer tube shows it expanded into tube sheet and individual aluminum fins positioned.





BRASS Bridgeport CO.

BRIDGEPORT BRASS COMPANY

Bridgeport 2, Conn. • Sales Offices in Principal Cities

Specialists in Metals from Aluminum to Zirconium

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AT COSDEN . . .

After five years' experience in operating Combin-aires, Cosden Petroleum Corporation, at its Big Spring refinery, has installed its FOURTH Hudson Combin-aire.

The Combin-aire is an integrated structure combining a water cooling tower with fin-tube hot fluid to air exchangers. Ambient air is cooled as it is drawn thru the water, and the cooled air serves as the cooling medium for the fin-tube coolers. Thus, with fin-tube coolers, effluent process stream temperatures may be reduced far below those obtained with ambient air.

The Combin-aire may be used primarily as a cooling tower, with the advantages of double use of air, and, because hot effluent air is undersaturated, complete elimination of spray carry over or condensation. Or when water is scarce, or salt, or brackish the Combin-aire may be used primarily for fin-tube cooling, using minimum water of any quality for pre-cooling air.

DEPENDING UPON DESIGN OBJECTIVES THE COMBIN-AIRE MAY HAVE SOME OR ALL OF THE FOLLOWING ADVANTAGES:

- Absolute minimum water consumption consistent with attainment of low terminal process stream temperatures.
- Water circulation may be made automatically responsive to air temperatures with no water circulated except at high ambient temperature.
- No water treatment necessary. Salt water or brackish water may be used.
- No spray carryover or condensation. After passing across the fin-tube elements the heated air leaving the Combin-aire at elevated temperature is undersaturated with water vapor and cannot precipitate condensate or carry water spray.
- Minimum piping. Combin-aire may be installed immediately adjacent to other process equipment.
- Clean air to fin-tube units. During the hot season air is washed, removing dust, sand and insects.

Effluent temperatures of process streams may be accurately controlled with HUDSON Auto-variable pitch fans.

HUDSON

ENGINEERING CORPORATION

BRAEBURN STATION • HOUSTON, TEXAS

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Photo Courtesy Bell Helicoptor Corporation, Ft. Worth, Texas

TUFFY GIVES SLING USERS A "LIFT"

in operating efficiency and economy

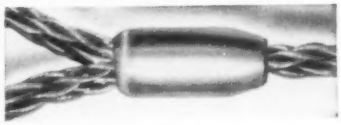
What else gets a lift with Tuffy? Just about everything. In every industry where loads are lifted, lowered, pulled or towed. On land and sea and even (as the picture suggests) in the air.

Jobs done by slings and hoist lines vary greatly. That's why Tuffy engineers have specialized in tailoring Tuffy products to specific uses.

Because of this specialization, Tuffy assures you the right sling for the job. Gives you better sling performance, greater safety and longer service life. In the long run, the ultimate low cost sling is Tuffy.

Don't take less than these Tuffy advantages . . .

Tuffy's secret of longer life: patented 9-part machine-braided fabric. It provides a combination of flexibility and strength never achieved by ordinary wire rope. Amazing resistance to kinks, which smooth out easily when they do occur.



An eye for strength and safety: Tuffy's metal ferrule gives the eye splice full strength of the fabric. That's because it's pressed on under tremendous hydraulic power. What's more, the smoothly tapered body won't snag hands. A Tuffy extra at no extra cost.

Get in Touch with Your Tuffy Distributor

Whether your sling jobs call for the Tuffy machine-braided sling, or Union's new 6- and 8-part hand-braided slings, your Tuffy distributor gives you by far the best buy. And he's famous for fast service on every sling and wire rope need. Look him up in the Yellow Pages.

Tuffy® Tips

—on safe use of

Slings and Hoist Lines

Lifting Strains Take High Toll of Injuries

Did you know that in some states one of every six compensation claims involves back injuries? And that one major insurance company says back injuries constitute 60% of their claim expense?

Hernia is another hazard of materials handling. One manufacturer reported 75% of his compensation claims involved hernias. This high incidence of hernias and back injuries can be greatly reduced by proper lifting equipment and methods.

How to Play It Safe When Loading Slings and Hoist Lines

1. Keep pull on sling legs in a straight line never shorten legs with knots or I-bolts. If choker and basket hitches are used on slings, check rated load limits.
2. Load slings on the center of hooks. Never at their points, except for hooks specially designed for point loading.
3. Never use load hooks that are bent open. They have been overloaded, and may drop loads with disastrous results. Same goes for defective chain blocks. Insist that your men report them at once.
4. Lubricate wire ropes at regular recommended intervals, with lubricant advised by your local oil company engineer.

FREE!
New Tuffy
Sling Handbook

All about slings from A to Z, including types, dimensions and rated loads. Address **Union Wire Rope Corporation, 2284 Manchester Ave., Kansas City 26, Missouri.** Specialists in high carbon wire, wire rope, braided wire fabric, and stress relieved wire and strand.

6

UNION Wire Rope

Subsidiary of ARMCO STEEL CORPORATION

OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division • The National Supply Company
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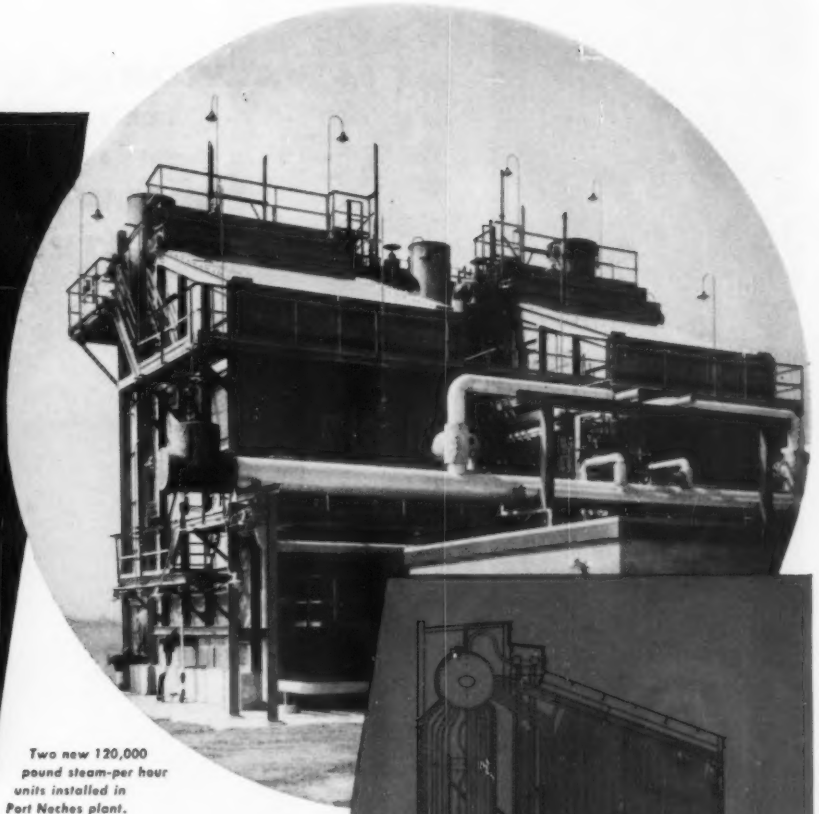
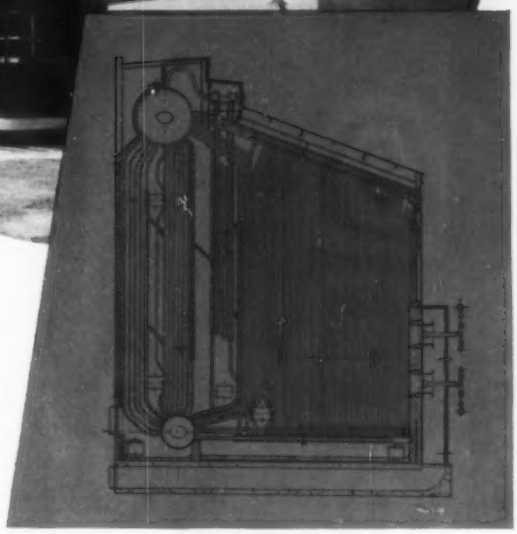
Steam for Jefferson Chemical by Vogt



Two new 120,000 pound steam-per hour units installed in Port Neches plant.



The needed additional power and process steam capacity for Jefferson Chemical's expanded Port Neches plant is furnished by the two Vogt boilers pictured here, each with a capacity of 120,000 pounds per hour. The boilers are designed for 675 lbs. pressure to operate at 625 lbs. pressure and 769°F. total temperature. The furnaces are equipped with gas burners and have water cooled front and side walls.

Bulletins describing Vogt boiler installations in a variety of industrial plants for power, processing and heating are available on request.

Installation by C. F. Braun and Co., Engineers.

For Custom Installation Bulletin VF-VS-2 • Package Unit Bulletin PSG-3, address Dept. 24A-BPR

HENRY VOGT MACHINE CO., LOUISVILLE, KENTUCKY

SALES OFFICES: New York, Chicago, Cleveland, Dallas, Camden, N.J., St. Louis, Charleston, W.Va., Cincinnati

Custom Built By..

STEAM GENERATORS

Vogt

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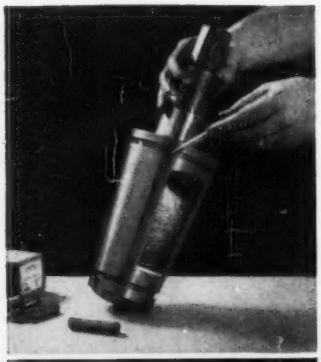
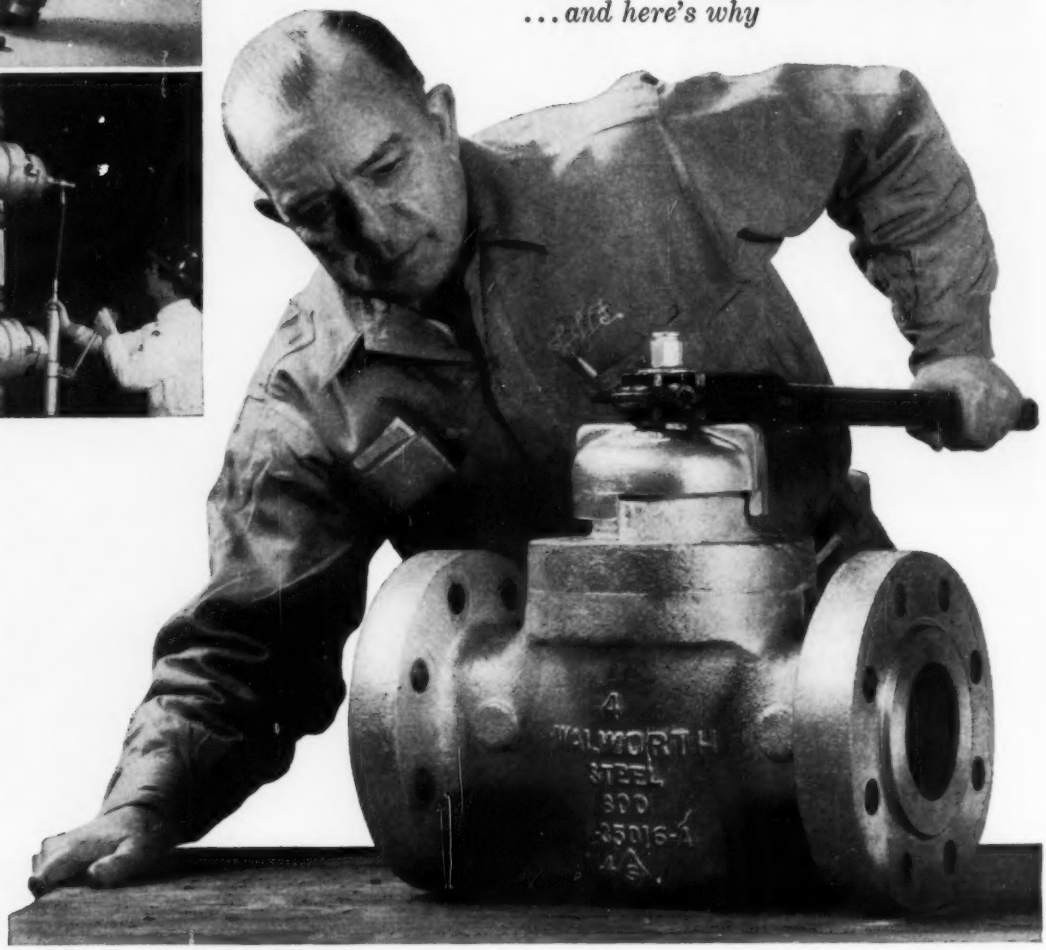


the **WALWORTH CUSTOMER**
wants a quick operating,
sure, tight valve. He chooses a

WALWORTH
LUBRICATED PLUG VALVE
...and here's why



When the Walworth Customer has to decide on a valve that will close fast and easily, he wants to know HOW fast... HOW easily. Tight closure? Of course. But can the valve be serviced under pressure? Yes. Still, he tries one himself.

In the Walworth Lubricated Plug Valve he finds 100% tight closure because it is lubricant-sealed against leakage. He finds it opens or closes with a quarter turn. Then, and only then, he's ready to buy. If that's the way you like to buy valves, become a Walworth Customer. For details on all types and ratings of Walworth LPV's, write Walworth Company, Lubricated Plug Valve Division, 3517 Polk Avenue, Houston 23, Texas.

Or write **WALWORTH** *750 Third Avenue, New York 17, N. Y.*
DISTRIBUTORS IN PRINCIPAL CENTERS THROUGHOUT THE WORLD

WALWORTH SUBSIDIARIES: ALLOY STEEL PRODUCTS CO. • CONOFLOW CORPORATION • GROVE VALVE AND REGULATOR CO. M&H VALVE & FITTINGS CO. • SOUTHWEST FABRICATING & WELDING CO., INC. • WALWORTH COMPANY OF CANADA, LTD.

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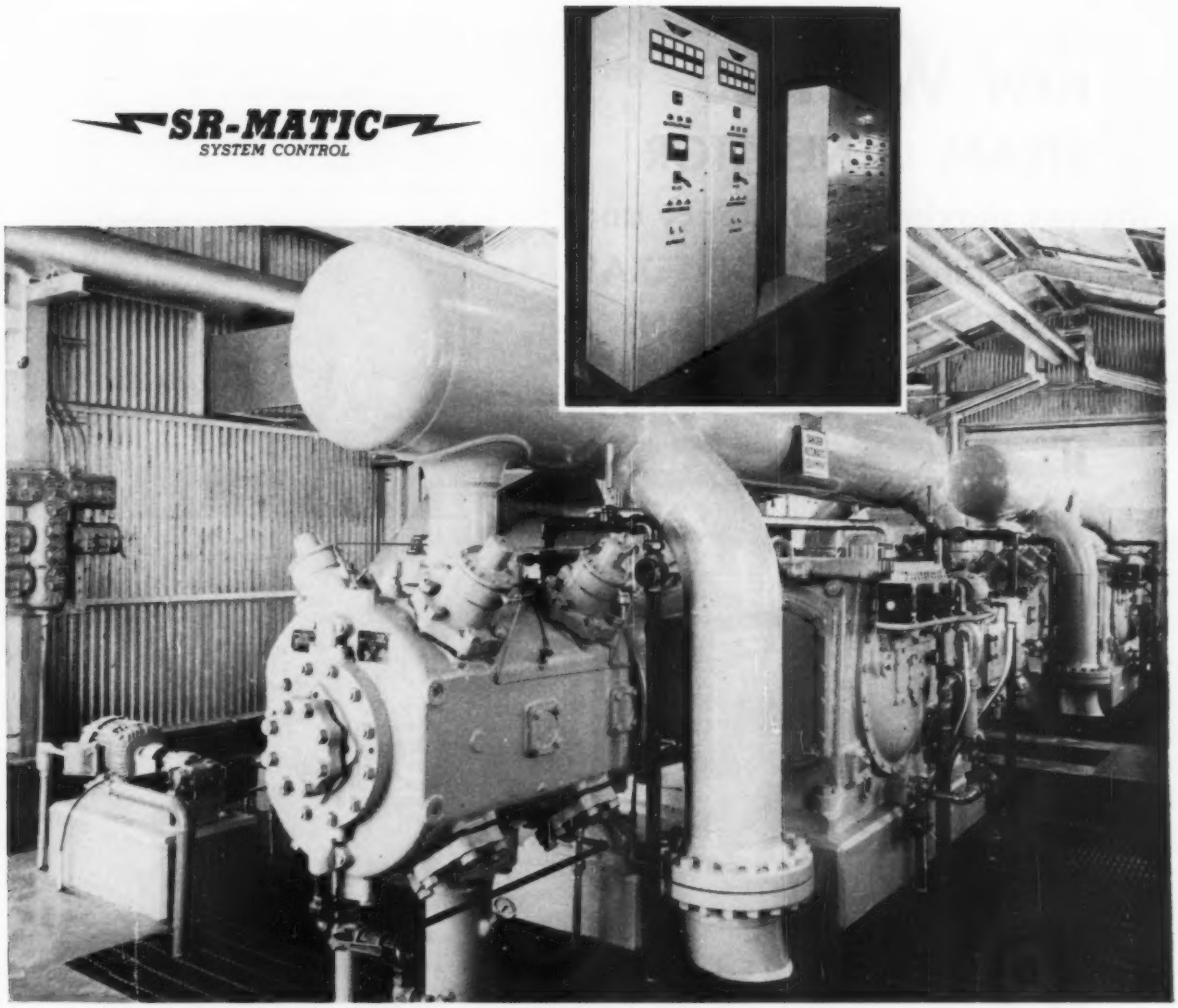
SR-MATIC
SYSTEM CONTROL



"DECISIONS...DECISIONS...DECISIONS"

all made by SR-MATIC, the system that thinks for itself!

From a remote or local set-point, SR-MATIC automatically selects and controls every function of compressor station operation. Manual attendance is reduced to any desired level. Operation has greater safety, continuity and efficiency with SR-MATIC control system by Stearns-Roger, specialists in process plant design and construction.

Stearns-Roger
THE STEARNS-ROGER MFG. CO. • DENVER, COLORADO

P. O. Box 5888, Denver 17, Colorado
DENVER • HOUSTON • SALT LAKE CITY

STEARNS-ROGER ENGINEERING COMPANY, LTD., CALGARY

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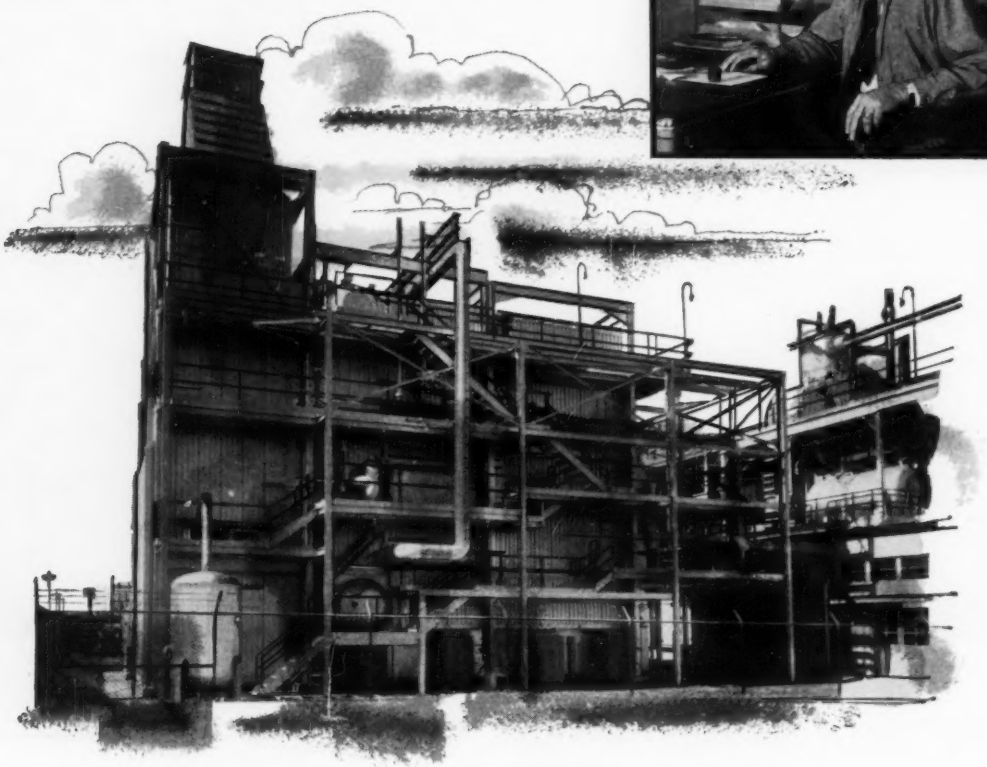
NEW WICKES STEAM GENERATOR

insures maximum efficiency and dependability for BRYAN, TEXAS, MUNICIPAL POWER PLANT

Calvin W. Beard, Superintendent of the Electric Utilities of Bryan, Texas, Municipal System: "As in every other power plant, our steam generator must give completely dependable performance day in and day out".



This Wickes Type RB 2 drum boiler is designed to produce 220,000 lbs. of steam per hour at 875 psig and 900° total steam temperature for the city of Bryan, Texas. The unit performs not only with remarkable dependability, but with Wickes' usual efficiency and economy. Wickes Boiler Co. builds steam generators in sizes to 500,000 lbs. of steam per hour, for high or low steam pressures and temperatures and for all types of fuels and firing methods. See your nearest Wickes representative for full information on a Wickes steam generator designed to suit your needs.

WICKES

RECOGNIZED QUALITY SINCE 1854

Sales Offices: Atlanta • Boston • Charlotte, N.C. • Chicago • Cleveland Dallas • Denver • Detroit • Houston • Indianapolis • Los Angeles • Memphis • Milwaukee • New Orleans • New York City • Philadelphia • Portland, Ore. • Rochester, N.Y. • Saginaw • San Francisco • Seattle, Wash. Springfield, Ill. • Tulsa

Bulletin 55-1 gives details of a wide variety of designs and sizes of Wickes field-erected and shop-assembled steam generators. Write for your free copy.

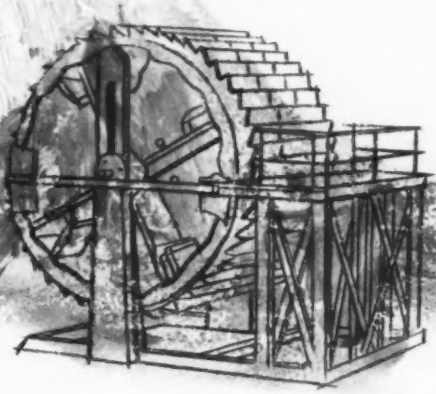
174

WICKES BOILER CO., SAGINAW 18, MICHIGAN, DIVISION OF THE WICKES CORPORATION

THE QUALITY OF THINKING

From an almost unlimited scope of thought, Leonardo da Vinci brought forth a stream of inventions which — in modern form — are in use today. However, Leonardo's greatest contribution was simply the triumph of creative thought applied to practical results. His work will stand for all time as proof that the appraisal of quality applies to thinking as well as to tangible objects and to visible or audible processes.

In a related sense, the quality of engineering is measured by results. And it is by results alone that the minds responsible for an engineering project can be evaluated. When you check the record of Brown & Root's engineering through the years, the high quality of thinking is self-evident. Customer satisfaction from greater efficiency at lower costs has built a worldwide reputation for engineering and construction by Brown & Root.



This squirrel-cage blower, invented by Leonardo da Vinci and put to practical use, was a significant step toward modern mechanical air conditioning.

BROWN & ROOT, INC.

Engineers · Constructors

POST OFFICE BOX 3, HOUSTON 1, TEXAS

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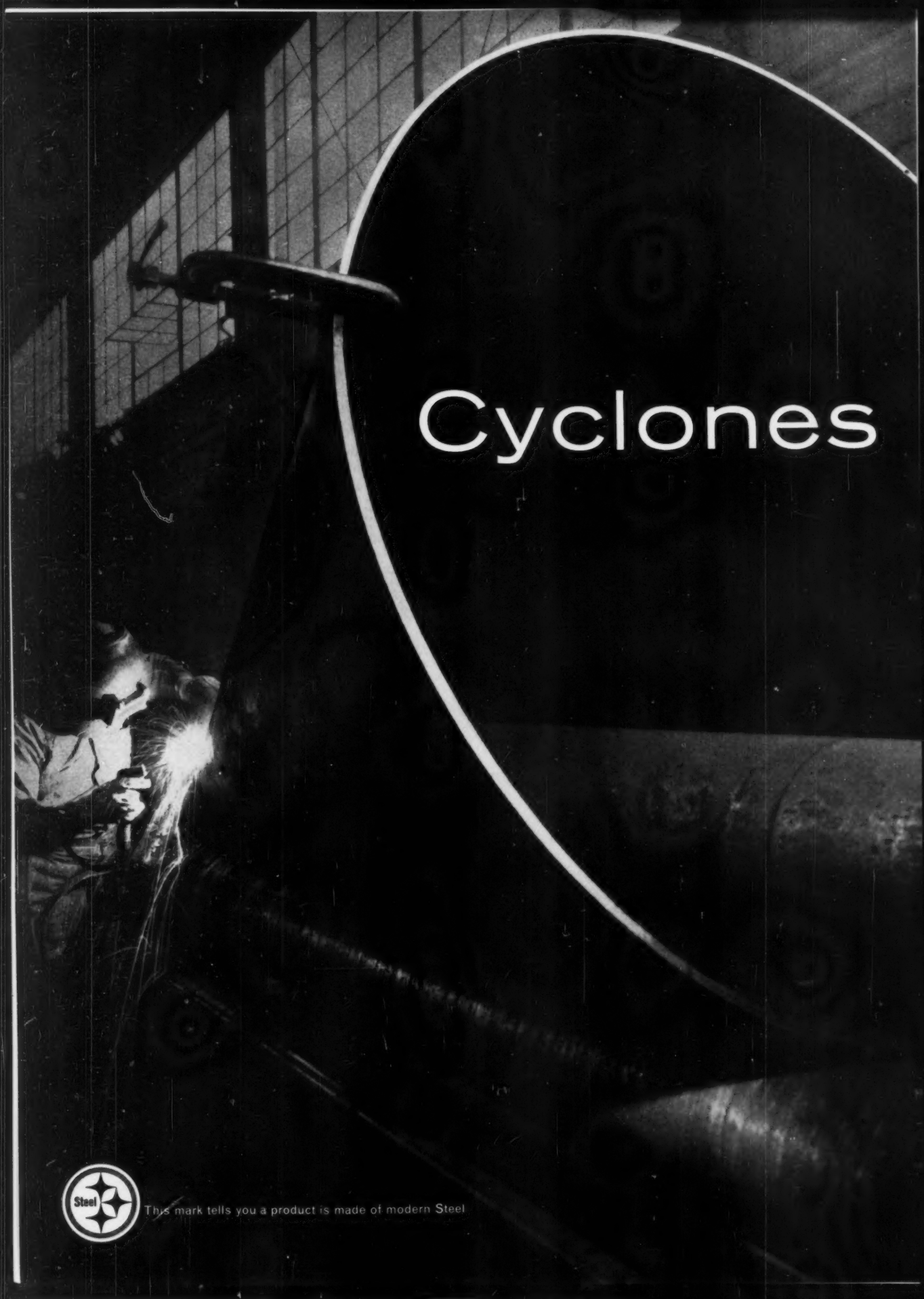
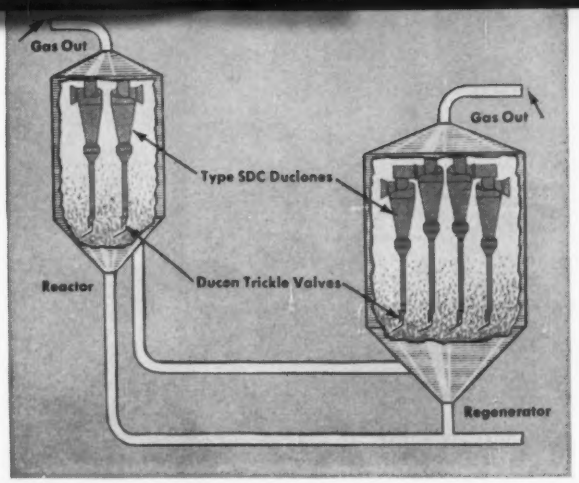

Cyclones
Steel
This mark tells you a product is made of modern Steel



General arrangement of Ducon cyclones in the reactor and regenerator of a fluid catalytic cracking unit. Stainless cyclone collectors keep catalyst loss to a minimum. "Duclone" is a registered trademark of the Ducon Co.

start here...

. . . and end up in fluid bed cat crackers where they circulate up to 60 tons of catalyst every minute. At $400 to $500 a ton, lost catalyst can put a lot of red ink into a refinery's operating budget. Breakdowns cost from $20,000 to $50,000 a day. That's why it is so important to design with the right material from the start: USS Stainless Steel.

Stainless Steel cyclones used for catalyst recovery are subjected to extreme heat and erosion. Temperatures in a regenerator unit can go as high as 1400° F. At high temperatures elemental sulfur corrosion would eat out most materials in nothing flat. Not Stainless. And Stainless Steel retains its strength at high temperatures. Stainless cyclones aren't in danger of changing shape which could cause catalyst loss.

Nothing equals Stainless Steel as a solution to the many complex problems in a refinery. It has outstanding corrosion resistance for a wide range of reagents, excellent high temperature strength. Its smooth, dense surface won't harbor contamination, is easy to clean. Above all, USS Stainless Steel promises long life and low maintenance. Order USS Stainless Steel through your USS representative or your local Steel Service Center.

If you are interested in more information about these Stainless Steel cyclones, wire or write U.S. Steel, Room 6104, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

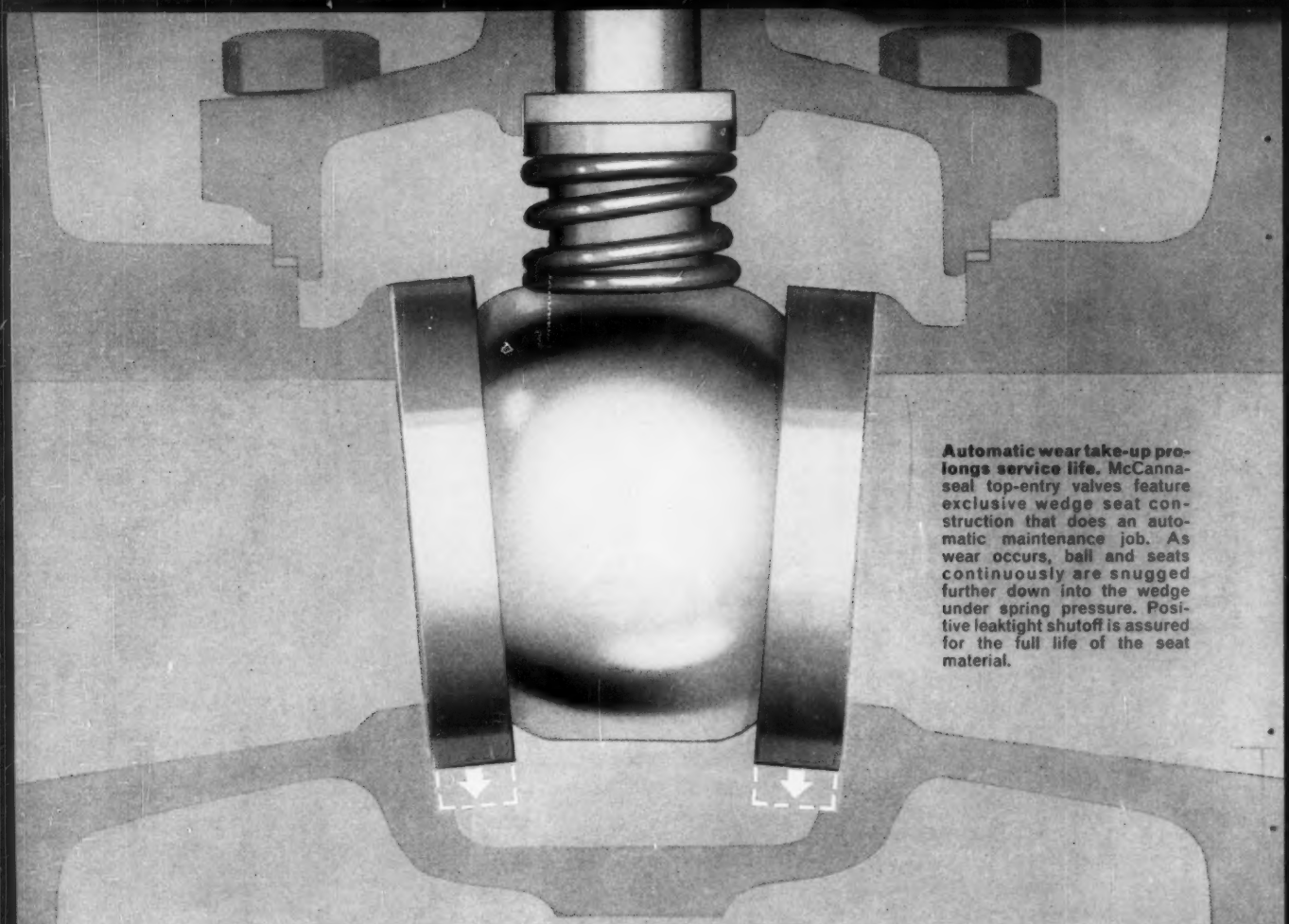
USS is a registered trademark

Left, welder completes longitudinal seam of one segment of the cyclone at The Ducon Company's Mineola, N.Y. plant. **Below,** stainless steel cone is removed from the forming rolls.

USS

United States Steel Corporation—Pittsburgh
American Steel & Wire—Cleveland
National Tube—Pittsburgh
Columbia-Geneva Steel—San Francisco
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Supply—Steel Service Centers
United States Steel Export Company

United States Steel

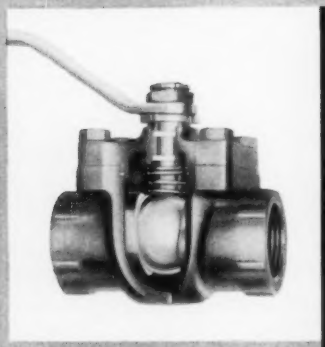


Automatic wear take-up prolongs service life. McCannaseal top-entry valves feature exclusive wedge seat construction that does an automatic maintenance job. As wear occurs, ball and seats continuously are snugged further down into the wedge under spring pressure. Positive leaktight shutoff is assured for the full life of the seat material.

McCannaseal Top-Entry Ball Valves

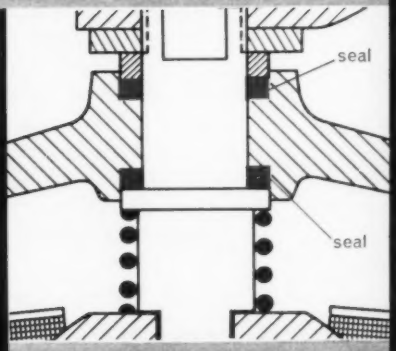
. . . the valves with wedge seat design that automatically adjusts for wear

New catalog gives complete data all types Hills-McCanna ball valves ¼" through 8", for pressures to 1000 psi, temperatures to 450°, manual or motor-operated. Includes dimensions, materials, C_v values, corrosion-resistance data—everything required for selection and piping layouts. Send for your copy today.



Fast quarter-turn operation from full-open to full-close. Screwed, flanged, or socket weld connections 2" to 8" sizes.

In-line maintenance. Simply remove ball and seats, reassemble with new seats, and you're back in business in a matter of minutes.



Leaktight stem seal. Double seals are under compression at all times—and the higher the line pressure, the tighter the seal.

A complete line of standard and special top-entry and bar stock valves for gases, liquids, vacuum . . . including models with high temperature and secondary fire seats.

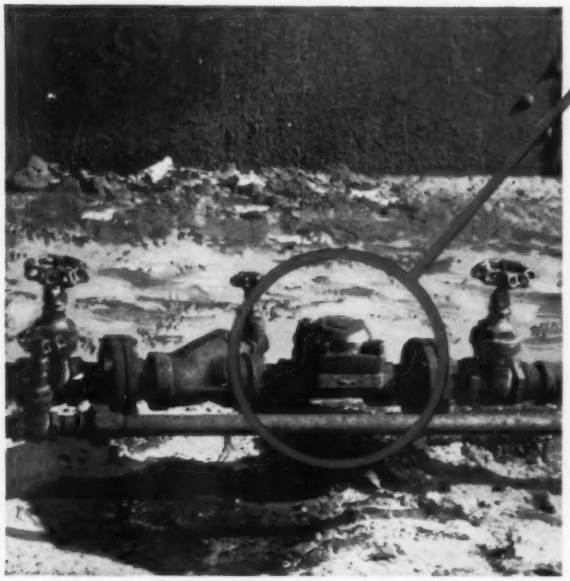
"McCannaseal" is a registered trademark. Patents pending.

HILLS-McCANNA COMPANY

4600 WEST TOUHY AVENUE, CHICAGO 46, ILLINOIS

YARWAY news briefs

from **Yarnall-Waring Company,** *Philadelphia 18, Pa.*
BRANCH OFFICES IN 19 UNITED STATES CITIES • SALES REPRESENTATIVES THROUGHOUT THE WORLD • STEAM TRAPS STOCKED AND SOLD BY 270 LOCAL INDUSTRIAL DISTRIBUTORS



THIS STEAM TRAP WILL DISCHARGE 25,500 LBS. OF CONDENSATE PER HOUR

This is a typical installation of a Yarway Series 40 Impulse Steam Trap—a trap designed specifically to gobble up extra heavy condensate loads.

The trap is a No. 48, 2½" size, and is installed on a suction heater connected with an 86,000 barrel tank containing fuel oil at a storage terminal. The operating pressure is 13 psi. At this pressure the trap has a capacity of 25,500 lbs. continuous discharge of condensate per hour.

At operating pressure of 100 psi, the trap's capacity is 62,000 lbs. per hour.

CAPACITY—PLUS

Capacity isn't the whole story on Yarway Series 40 Steam Traps. Like all Yarway Impulse Traps, they offer advantages like quick heat-up, even temperatures, small size, good for all pressures, non-freezing.

Series 40 traps also feature high temperature discharge characteristics, excellent low pressure operation, no airbinding, operation against back pressures up to 40%, and stainless steel construction.

You can get Yarway's latest steam trap Bulletin T-1743, or arrange for a free 60-day trial of a Yarway Impulse Trap, by writing to Yarnall-Waring Company or contacting your local Industrial Distributor.

Yarway ½" No. 40 Impulse Steam Trap (shown actual size). Also available in ¾", 1½", 2" and 2½" sizes.

YARWAY OFFERS IMPULSE STEAM TRAPS FOR THESE SPECIFIC OPERATING CONDITIONS

AVERAGE CONDENSATE LOADS	EXTRA HEAVY CONDENSATE LOADS	LIGHT CONDENSATE LOADS
Series 60	Series 40	No. 30

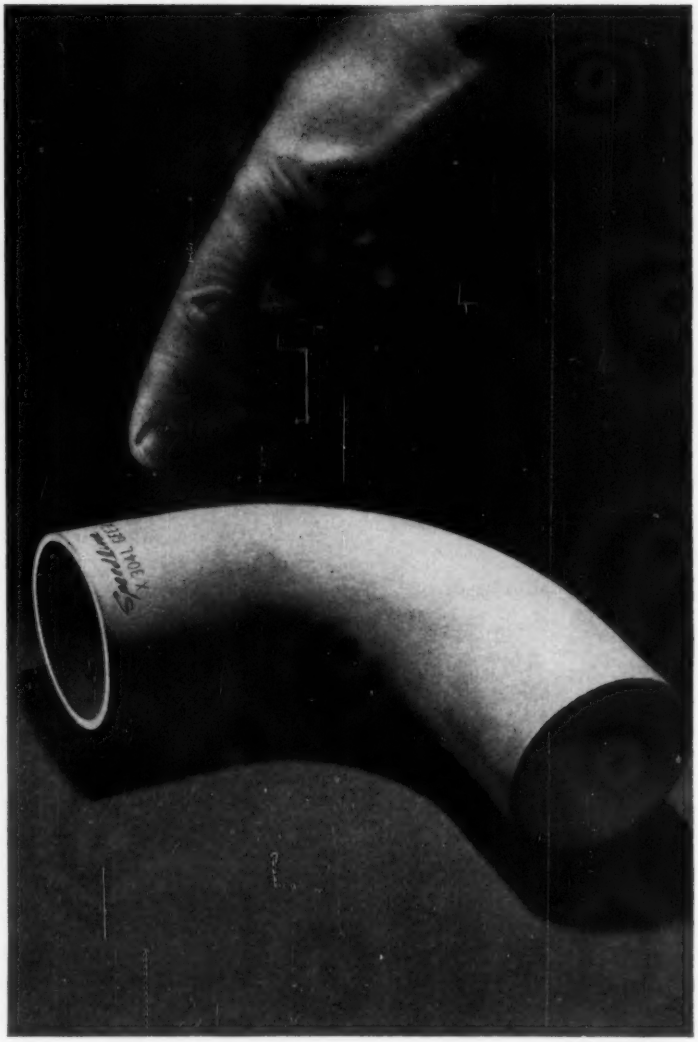
For more data on advertised products, use Readers' Service Cards, last page.

THERE IS A DIFFERENCE IN PIPE FITTINGS

CHECK THESE *Speedline*® FEATURES

THEY INSURE QUALITY . . . IMPROVE PERFORMANCE

- ✓ **Uniform Wall Thickness at the Bend —in accordance with Specification MSS-SP-43**
- ✓ ***Every* Stainless Steel Fitting Annealed and Pickled**
- ✓ ***Every* Fitting marked with Size, Analysis, Schedule and Production Code**
- ✓ **Certified Chemical Analysis Available on *All* Fittings**
- ✓ ***Complete* Fitting Line — including Eccentric Reducers, Crosses, Reducing Tees, etc.**
- ✓ ***Full Flange Thickness*—to ASA Dimensions**
- ✓ ***Complete* Selection of Metals—Stainless Steel, Aluminum, Hastelloy, Titanium, Zirconium, Carpenter 20**



***Plus* . . . SPEEDLINE STAINLESS STEEL FITTINGS ARE AVAILABLE FROM *STOCK*—*IMMEDIATE DELIVERY* CAN BE MADE BY DISTRIBUTORS THROUGHOUT UNITED STATES AND CANADA**

Speedline are the *original long tangent fittings* with the "extra length" feature—on *every* end of *every* fitting. Speedline design and manufacturing experience is your assurance of process pipe line dependability—*and* economy. Complete catalog data available on request.

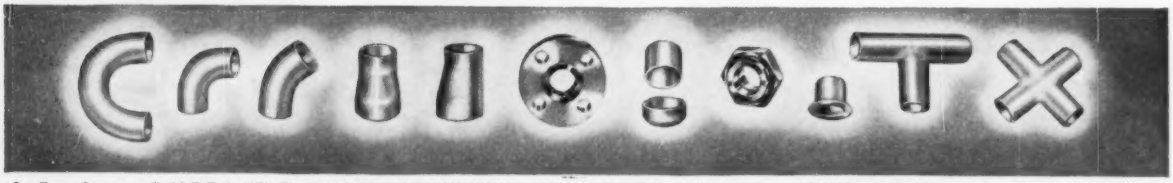
1001

Speedline®

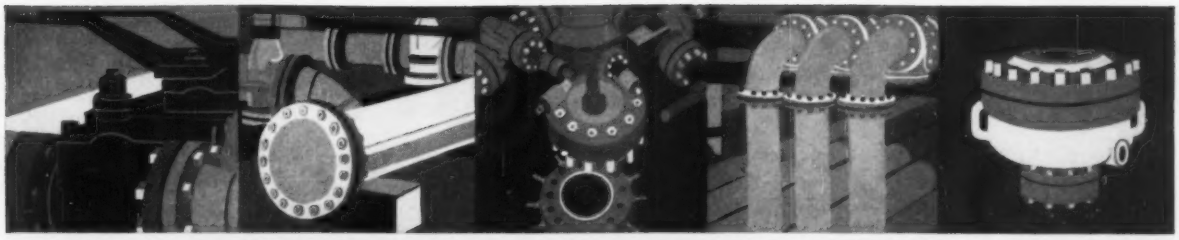
® REG. T.M. OF HORACE T. POTTS COMPANY

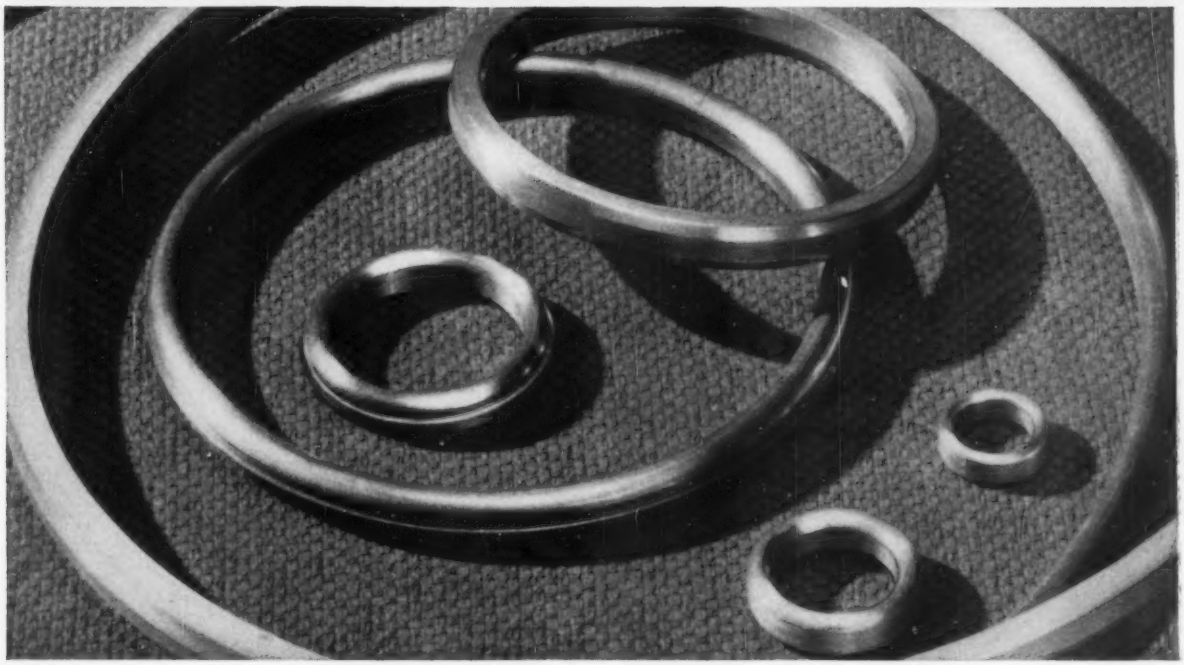
CORROSION-RESISTANT FITTINGS

STAINLESS STEEL • ALUMINUM • SPECIAL ALLOYS



A Product of HORACE T. POTTS COMPANY • 566 E. Erie Avenue • Philadelphia 34, Pennsylvania





Get safer, surer sealing in ring-grooved joints with J-M V-TITE® GASKETS

YOU WILL BENEFIT BY CHOOSING THE GASKET PROVED IN SO MANY APPLICATIONS!

If you are concerned with the design or maintenance of ring-type joints, it will pay you to insist on the tighter, more efficient and longer-lasting seal you get with J-M's V-Tite design. Many equipment builders install these outstanding gaskets, and if it's your job to keep this equipment operating at top efficiency, here's a good point to remember: the gaskets that are right to *start* with . . . are right to *stay* with.

V-Tite Gaskets are "right" because every step in their manufacture is meticulously performed. Close tolerances are rigidly maintained for matching of rings with flange grooves. Carefully-controlled annealing keeps gasket hardness well below flange hardness . . . to assure proper flow and sealing without damaging the flange surfaces. Contact surfaces are smoothly finished . . . with no ridges, no tool or chatter marks that cause joint leakage.

J-M produces a wide selection of custom-designed and standard gaskets in any material, dimension or cross-section you require . . . including the new pressure-actuated BX Ring Gasket for extreme pressure service up to 15,000 psi at temperatures up to 250 F.

Complete information from your J-M Distributor. Or write to Johns-Manville, Box 14, New York 16, N.Y. In Canada: Port Credit, Ontario.

JOHNS-MANVILLE JM PRODUCTS

V-Tite Gaskets meet API specifications

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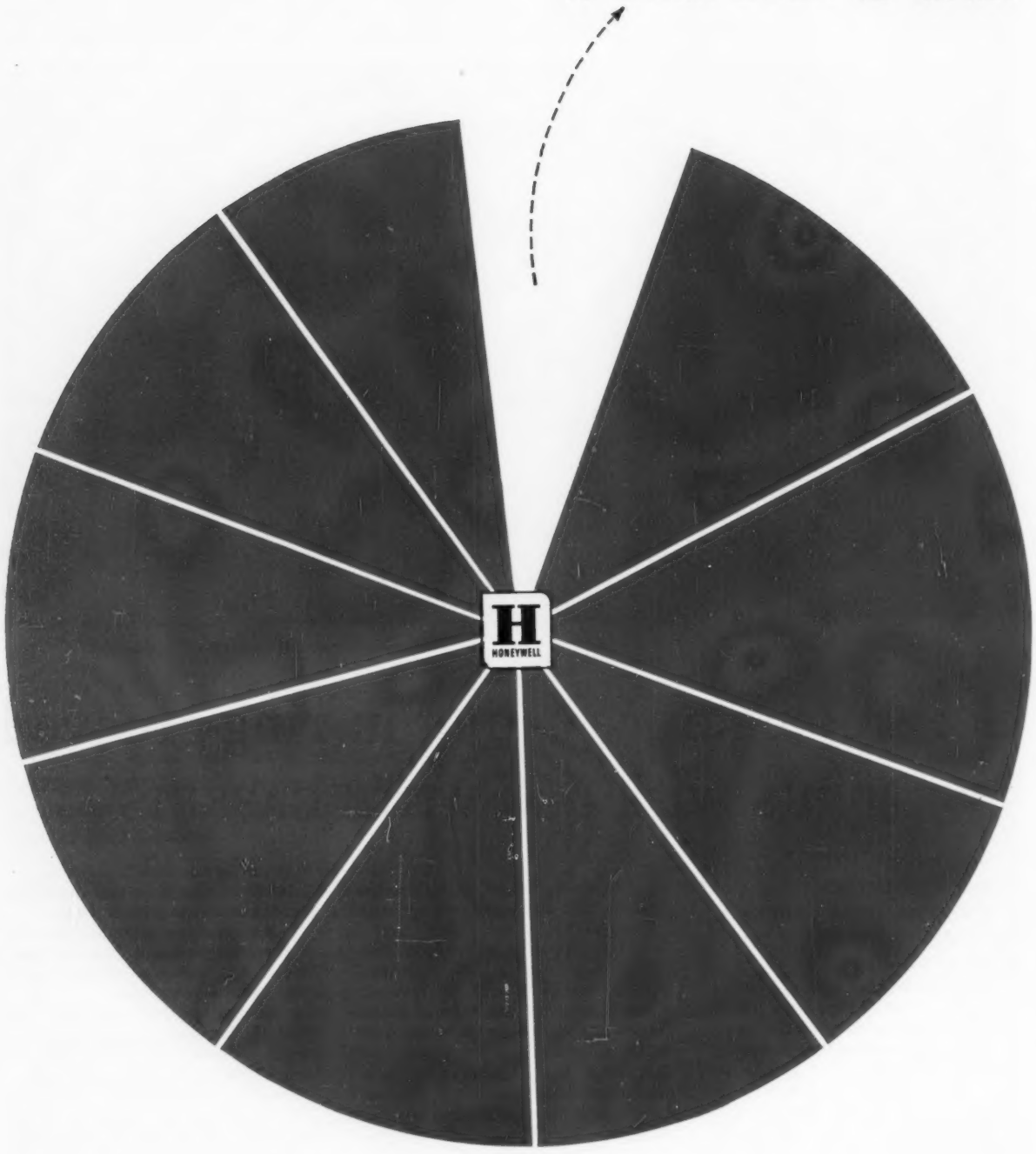
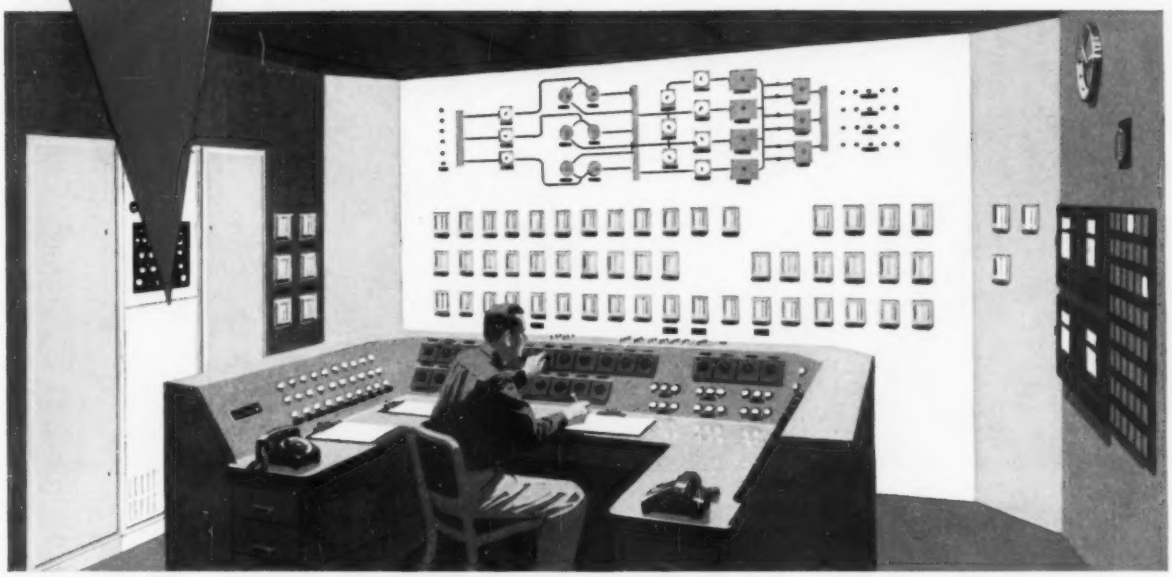
A COMPUTER IS ONLY



PART OF A PROCESS CONTROL SYSTEM



You hear a lot about industrial process computers these days. As processes get bigger, faster and more complex, computers are being used as the reins as well as the brains—for control as well as data reduction—in fields as diverse as ice cream making and petroleum refining.

The Big Picture. But like the human brain, a computer cannot work independently. It must receive raw information from sensory instruments. Where automatic control is involved, it must transmit its logic to "muscle" instruments which translate decisions into action. The computer is part of a system, and, like the human body, the system functions effectively only when all of its parts are perfectly coordinated. In Honeywell systems, this compatibility of *all* system components is built in, for all Honeywell instruments and controls are *made* to complement each other.

Process Experience plus Computer Know-How. Equally important, a computer must be properly applied. Computers are "illiterate." They must be told what to do and how to do it by men who know. In engineering a computer-directed instrumentation system that will be precisely matched to your needs, Honeywell systems engineers draw on more than 75 years of measurement and control experience.

Single-Source Responsibility. Honeywell offers you a single contract covering your entire system. You get economy, convenience, simplified training of personnel, economical stocking of parts and accessories—*all* the advantages of single-source purchasing. And you get the only truly complete computer control package available from a single source.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Penna. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

75th YEAR
PIONEERING THE FUTURE

Honeywell

First in Control

SINCE 1885

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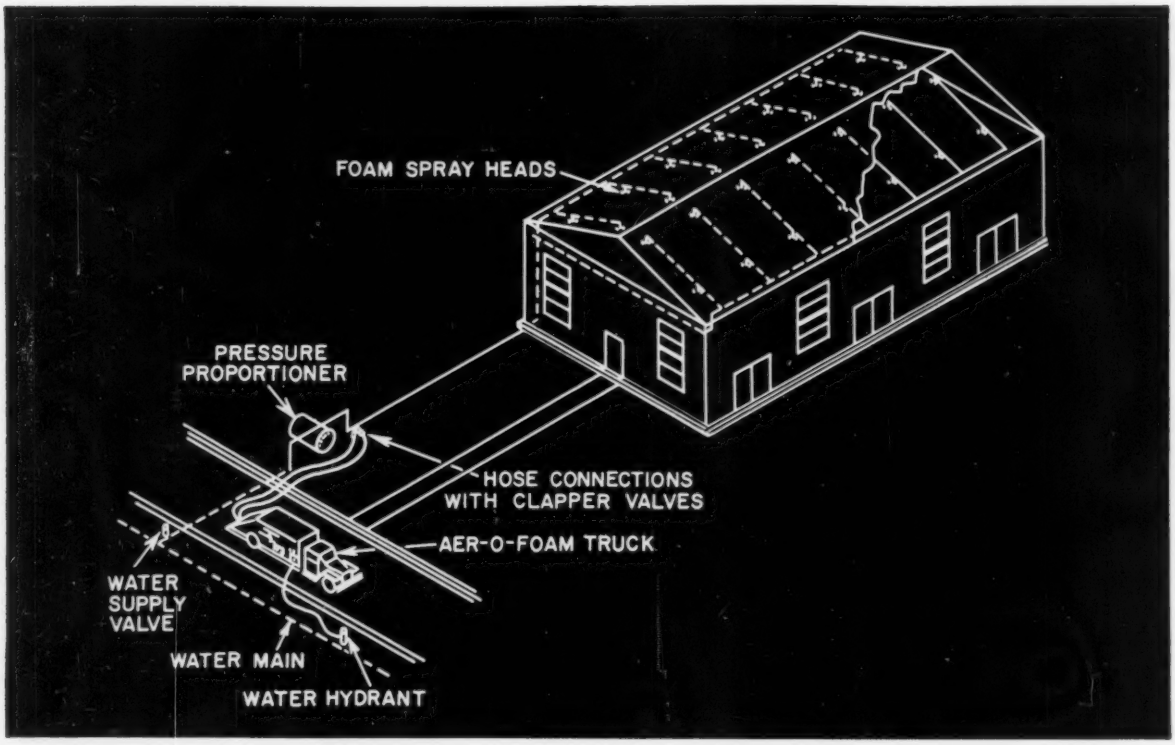

HOW TO USE FOAM TRUCKS

to protect additional refinery areas—at low cost

Pump houses, manifold pits, pipe trenches and other "hot spots" in refineries often lack the fixed fire protection systems found on storage tanks.

This condition can be corrected, promptly and inexpensively, with systems such as that shown in this diagram of a typical pump house.

Overhead foam spray heads are connected with a single pipeline leading back to a water source. At a point in this line, a proportioner holds a supply of Aer-O-Foam Liquid sufficient to operate the system for perhaps ten minutes.

In the event of fire, the operator opens the valve, starting foam discharge in a matter of seconds. At the same time, a foam truck is dispatched to the scene and hooks its discharge hose into the downstream side of the proportioner, providing ample foam liquid to operate until the fire is extinguished.

* * *

With every modern advance in design and construction, National Aer-O-Foam Trucks perform tasks like this efficiently and economically. These trucks are typical of National's contributions to better control of fire in flammable liquids.

National Foam System, Inc.

West Chester, Pa.

"There is much evidence that we are on the verge of a scientific revolution that will transform our world more rapidly and completely than did the industrial revolution in the nineteenth century. This transformation will give to millions of people wider opportunities to satisfy their basic needs, and among them will surely be the need for more products derived from oil." —M. J. Rathbone, President

Standard Oil Company (New Jersey)

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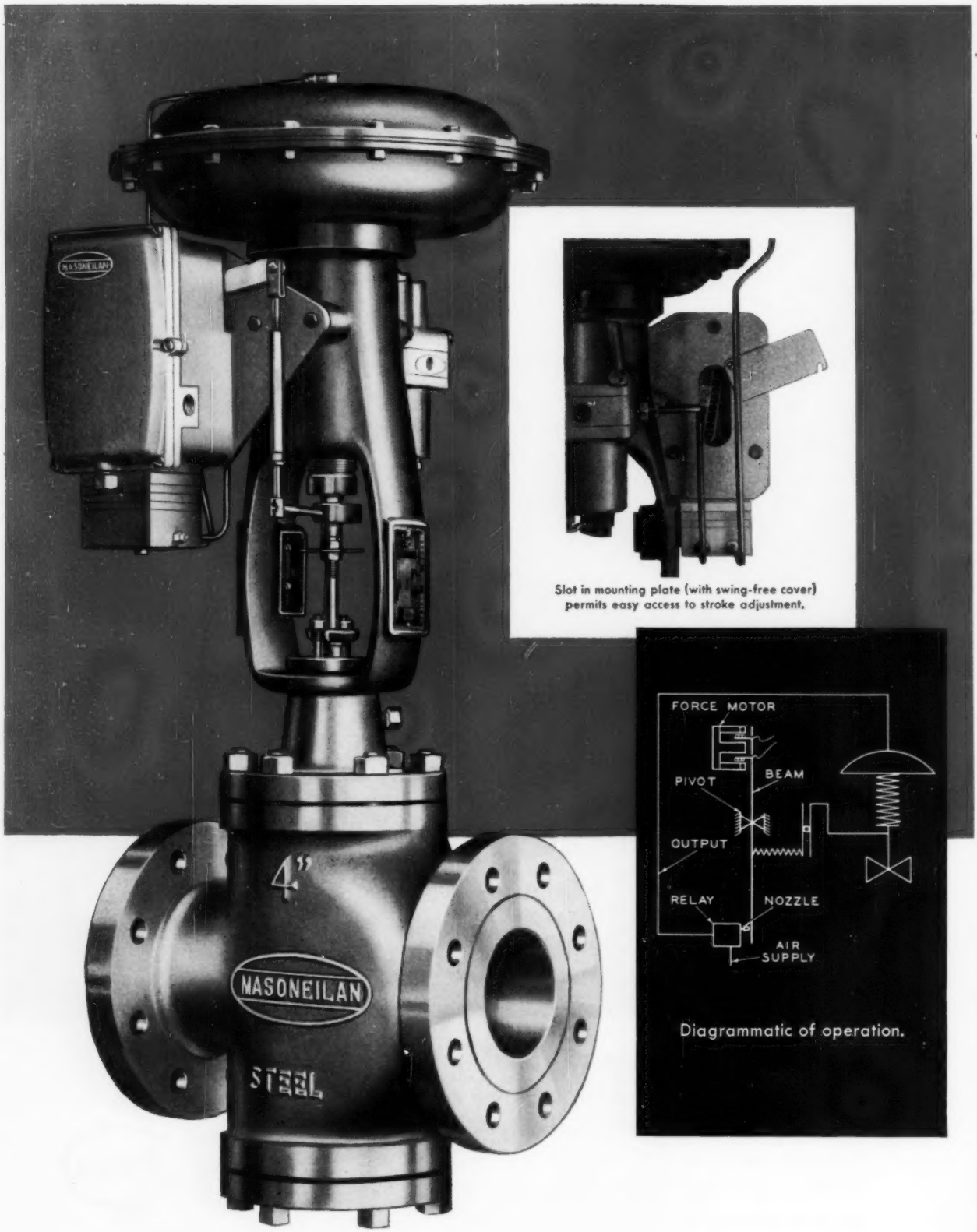
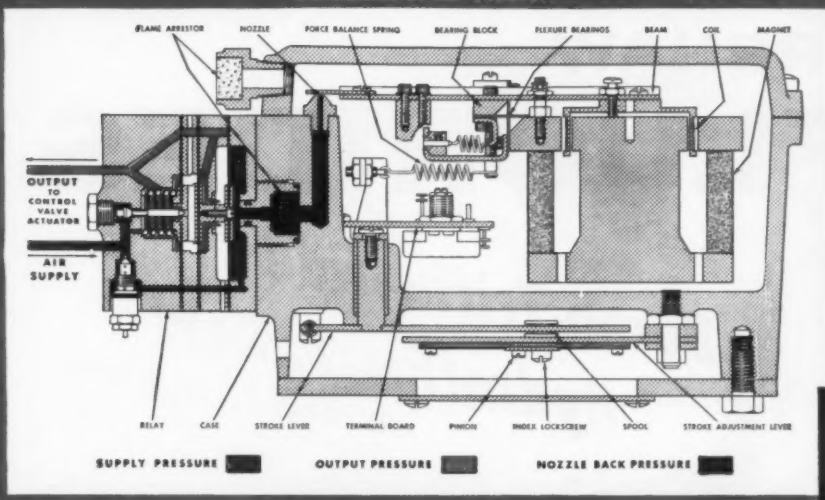


Model 8010 mounted on spring-diaphragm actuator. Note compact design.

Slot in mounting plate (with swing-free cover) permits easy access to stroke adjustment.

Diagrammatic of operation.

Schematic of air circuits.



Speed The speed of the positioner, with integral relay and normal 20 psi supply pressure, is tabulated below.

ACTUATOR SIZE	VALVE STROKE (inches)	SPEED (seconds)
9	½	1.5
	¾	1.8
11	¾	2.8
	1	3.3
13	1	4.9
	1½	6.3
15	1½	9.4
	2	11.4
18	2½	21
	3½	29
	4	32

Performance Data

Open-loop Gain* — approximately 100

Linearity — within ±1% of full stroke

Repeatability — within 0.2%

Load Sensitivity — Output pressure change of 1.2 psi per 0.1% of full stroke offset

Supply Pressure Effect — ±1% of full stroke for ±5 psi change from 20 psi

*Defined as $\frac{\%\text{ of full stroke}}{\%\text{ of full input range}}$

Now! Masoneilan Electropneumatic Positioner with Velocity Feedback

Combines high open-loop gain and closed-loop stability to give you Precise Positioning and Superior Dynamic Response

The new Masoneilan Model 8010 Electropneumatic Positioner offers optimum performance plus these design advantages:

- A true positioner — *direct* comparison of valve stem position with controller output signal provides dynamic response and positioning accuracy not obtainable with transducer and pneumatic positioner combination.
- Electrical circuit easily adapted to a variety of controller output signals.
- Extra large stabilized magnet, plus efficient magnetic circuit, provides high force changes.
- Explosion-proof construction meets requirements of Class I, Division I, Group D.
- External stroke adjustment accessible without removal of cover — no exposure of electric wiring.
- High capacity relay for fast stroking speeds. Relay may be mounted in any one of four positions to facilitate piping.
- Balanced beam permits installation of valve in any position without shift in calibration.
- Available for 3-15 psi or 6-30 psi valve spring ranges and for split-ranging. Standard stroke ranges ⅜"–3" and 2"–4". Others available.
- Available with direct or reverse action and for direct or reverse actuators.

You can now utilize the desirable characteristics of electronic control and obtain the power and smooth throttling action of pneumatic valves by using Masoneilan Electropneumatic Positioners. Full details on request. Ask a Mason-Neilan representative or write direct —

MASONEILAN

MASON-NEILAN

Division of Worthington Corporation

51 NAHATAN STREET, NORWOOD, MASS., U. S. A.

Sales Offices or Distributors in Principal Cities in United States and Abroad

In Canada Worthington (Canada) Ltd., Mason-Neilan Division

MNO-19

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HARSHAW
FLUORIDES

Boron Trifluoride
Hydrofluoric Acid
ANHYDROUS . . . AQUEOUS

The uses for Fluorides are ever increasing. Harshaw Fluoride production also has increased steadily. Shipments of cylinders and tank cars leave our plant daily. If required, you are invited to draw on the knowledge and experience of our staff of technical specialists on Fluorides.

Write for your free copy of M.C.A. Chemical Safety Data Sheet SD-25 on properties and essential information about...
HYDROFLUORIC ACID
Anhydrous and Aqueous

THE HARSHAW CHEMICAL CO.
1945 EAST 97th STREET • CLEVELAND 6, OHIO
Chicago • Cincinnati • Cleveland • Detroit
Hastings-On-Hudson, N. Y. • Houston
Los Angeles • Philadelphia • Pittsburgh

Here is a helpful list of HARSHAW high-quality fluorides:

Ammonium Bifluoride
Ammonium Fluoborate
Barium Fluoride
Bismuth Fluoride
Boron Trifluoride Complexes
Chromium Fluoride
Copper Fluoborate
Fluoboric Acid
Fluorinating Agents
Frosting Mixtures
Hydrofluoric Acid Anhydrous
Hydrofluoric Acid Aqueous
Hydrofluosilicic Acid
Laboratory Fluorine Cells
Lead Fluoborate
Lithium Fluoride
Metallic Fluoborates
Potassium Bifluoride
Potassium Chromium Fluoride
Potassium Fluoborate
Potassium Fluoride
Potassium Titanium Fluoride
Silico Fluorides
Silicon Tetrafluoride
Sodium Fluoborate
Tin Fluoborate
Zinc Fluoborate
Zinc Fluoride

HARSHAW

What price luxury? Gasoline is taxed more than mink.

Indispensable gasoline is taxed an average 33%, Milady's mink—10%. When consumers complain, however, about "the high price of gas," they don't seem to know they now pay less (before taxes) for 100 octane gasoline than they did for 50 octane thirty-five years ago. They don't know that two gallons now do the work of three, saving them millions of dollars each year. They don't know, but you do. Next time you get a chance, tell them about it.

SHELL OIL COMPANY

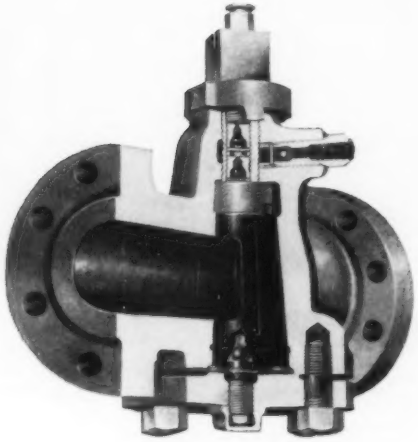
For more data on advertised products, use Readers' Service Cards, last page.

the idea:

Force Can Be Multiplied Through Hydraulics

Blaise Pascal in 1625 demonstrated that a given force can be multiplied almost infinitely through use of hydraulics. His principle: "a unit pressure applied to the liquid contained in a sealed vessel is transmitted to every part of the liquid with undiminished force, thus multiplying the force many times . . "

the application:



How It Helps Give You A Better Valve

In the Rockwell-Nordstrom valve (the *original* lubricated plug type), lubricant is injected under pressure creating powerful instantly replaceable seals against leakage in the Sealdport® grooves between plug and body. Lubricant also hydraulically jacks and balances the plug to maintain perfect seating, instant operation.

the benefits:

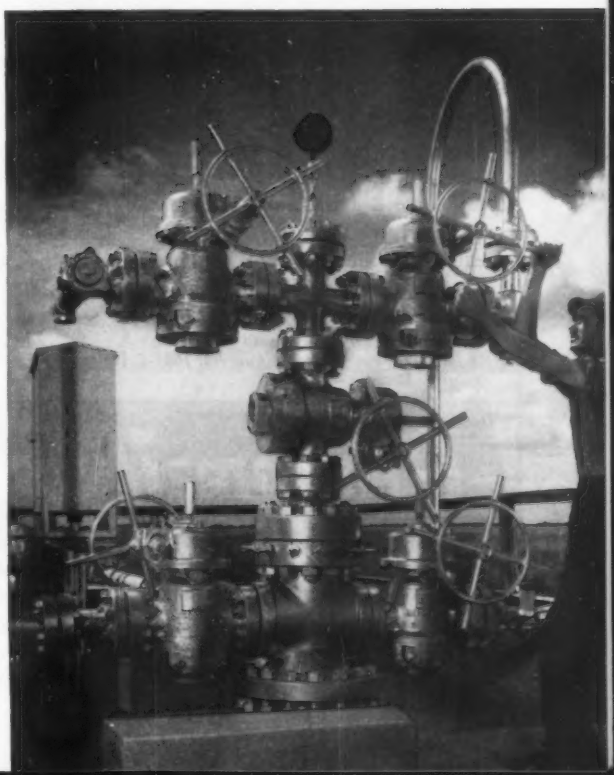
Positive Shut-Off . . . Instant 1/4-Turn Operation . . . Unexposed Seating, Longer Life, Lower Cost

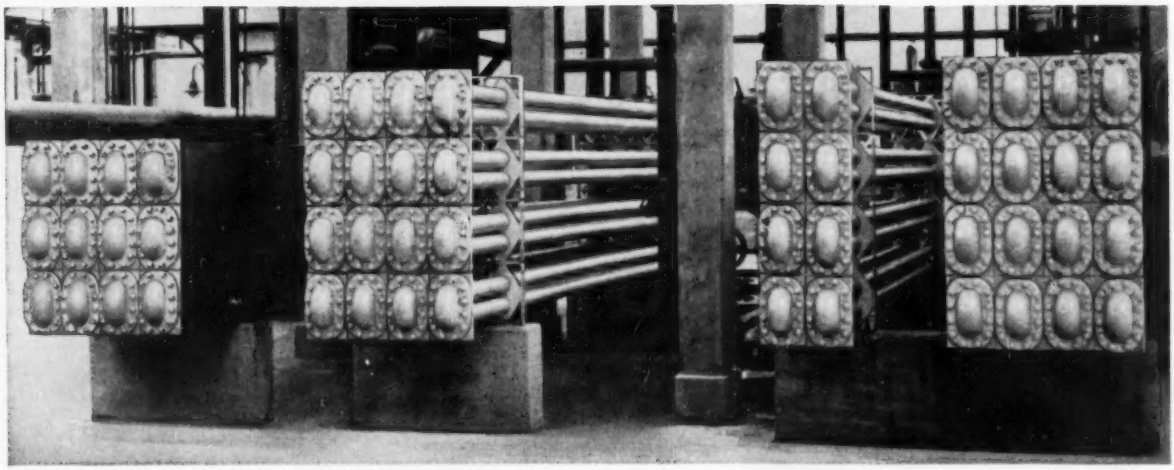
For a full range of services, Rockwell-Nordstrom lubricated plug valves insure the trouble-free operation and freedom from wear and repair that you can only expect from a *lubricated* mechanism. See your supplier or write for complete details on Rockwell-Nordstrom lubricated plug valves, lubricants and operating accessories. Or better yet, have a Rockwell field engineer visit you. Rockwell Manufacturing Company, Dept. 95-L, Pittsburgh 8, Pa. Canadian Valve Licensee: Peacock Brothers Limited. If you live outside the U. S. or Canada, write: Rockwell International S.A., Geneva, Switzerland.

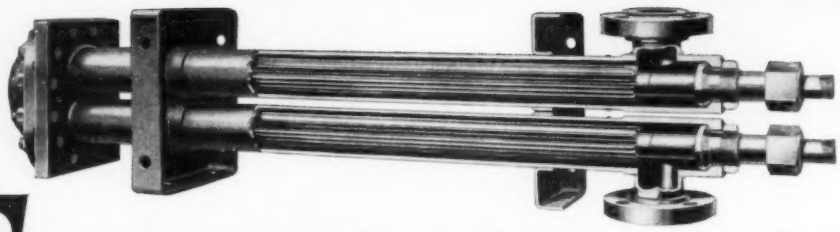
Lubrication Makes The Difference

ROCKWELL-Nordstrom VALVES
another fine product by
ROCKWELL

On Christmas tree service, absolute dependability is assured by hydraulic jacking of plug in Rockwell-Nordstrom valves . . . well-head control is fast, sure and leak proof.







G-R Twin G-Fin Heat Exchanger Sections

Field proved by more than 74,000 units for practically all heating and cooling services

G-R Twin G-Fin Sections are easy to handle, easy to erect and require practically no servicing. They can be used singly or connected in series, parallel or series-parallel banks to provide any capacity desired. Any installation can be enlarged or reduced simply by adding or removing the proper number of sections. Sections not needed can serve as stand-by for sections on line, or used at other plants.

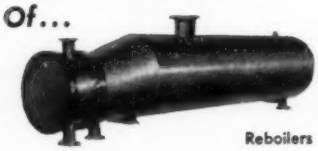
Use of our industry-proved extended surface G-fins overcomes unequal heating coefficients of fluids being handled, assuring more efficient heat transfer than if bare tubes were used, and the controlled flow through the longitudinal passages assures efficient operation. For the best performance by far, select G-R. Get full details.

Write for G-R Twin G-Fin Bulletin No. 1401-R Today!

Griscom-Russell

THE GRISCOM-RUSSELL COMPANY
222 Wetmore Avenue, **Massillon, Ohio** • Phone TEmple 2-8751
Engineering and Sales Representatives in the Principal Cities

Also Manufacturers Of...



Reboilers

Fin-Fan Coolers

G-R Shell and Tube Heat Exchangers, Feedwater Heaters, Twin G-Fin Sections, Scale-Shedding Evaporators, Tank Heaters, After-coolers, Steam Generators, Ship and Land Base Sea Water Distilling Plants, Fin-Fan Coolers, Recuperators and Finned Tubing.

C. H. WHEELER Power Plant Condensers and Vacuum Equipment, Water Supply Drainage and Circulating Pumps, and Marine Auxiliary Machinery.

THE GRISCOM-RUSSELL CO.
Massillon, Ohio
C. H. WHEELER MFG. CO.
Philadelphia 32, Penna.
Subsidiaries of
HAMILTON-THOMAS CORPORATION
Hamilton, Ohio

Why Solar designs industrial gas turbines to weigh between 1 and 1½ lb/hp

by Paul A. Pitt
Chief Engineer
Solar Aircraft Company

The weight of Solar gas turbines is the result of a design philosophy that is unique in the small gas turbine field.

Most gas turbine designs fall into one of two extreme categories. Aircraft-type engines, at one extreme, embody highly sophisticated techniques for extreme light weight in relation to horsepower, but have resulting short life. The opposite philosophy employs the ultra-massiveness of steam turbines to assure long life.

There are important disadvantages in both approaches when long life, reasonable cost, dependable operation, simple maintenance and easy transportation and installation are required. While aircraft-design engines (of ¼ to ½ hp/lb) can be modified and derated for longer service life, the resulting product is inherently delicate. This compromise inevitably results in short life.

Paul A. Pitt

On the other hand, massive design (of 10 lb/hp and up) leads to unnecessary structural bulk and introduces problems of thermal lag and distortion.

Since World War II, Solar has designed and built a variety of gas turbine units with characteristics that lead to both long life and low weight. The Saturn gas turbine engine, for example, is an 1100 hp unit intended specifically for industrial and military installations. It has a weight-to-power ratio of 1.1 to 1.4 lb/hp.

Although it is designed for long life, it utilizes only enough materials in its components to satisfy structural and thermal requirements. This approach resulted in a design that makes no compromises with durability and performance, yet meets the needs of industry for flexibility in a small package. It has an 1100 hp rating at a specific fuel consumption of 0.61 lb/hp-hr and a continuous rating of 1020 hp at 0.63 lb/hp-hr SFC.

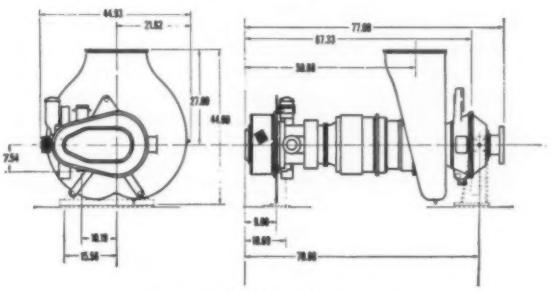
Meeting these objectives required an engine with a simple thermodynamic cycle and high efficiency components. An axial compressor was designed with an operating efficiency of 86%, and this was combined with a multi-stage, axial type turbine of advanced aerodynamic design. Over-all dimensions of the engine are shown in the figure below.

To fulfill workhorse service requirements, the engine was designed to operate at a conservative gas temperature of 1450 F continuous rating. The stress levels are also low, so that major rotating and stationary components will have more than 100,000 hours of life with long periods between overhaul. To keep costs down and assure dependability, the engine design is simple and straightforward.

In brief, the development program of the Saturn turbine adhered to three principles: Careful aerodynamic design for high performance; use of moderate temperatures and low stress levels for long life; and exhaustive component testing for ruggedness and reliability.

Presently scheduled field applications of the Saturn turbine include: Power source for 750 kw electric generator sets in process plants, portable field equipment, pipeline pumping, and gas compression in the petro-chemical industry. Other uses are as a power source for a 600 kw generator set in a commercial marine installation, propulsion units for marine and amphibious vehicles, and prime movers for off-highway vehicles.

Detailed data on Solar gas turbines and other turbomachinery is available. Write Dept. H-172, Solar Aircraft Company, San Diego 12, California.

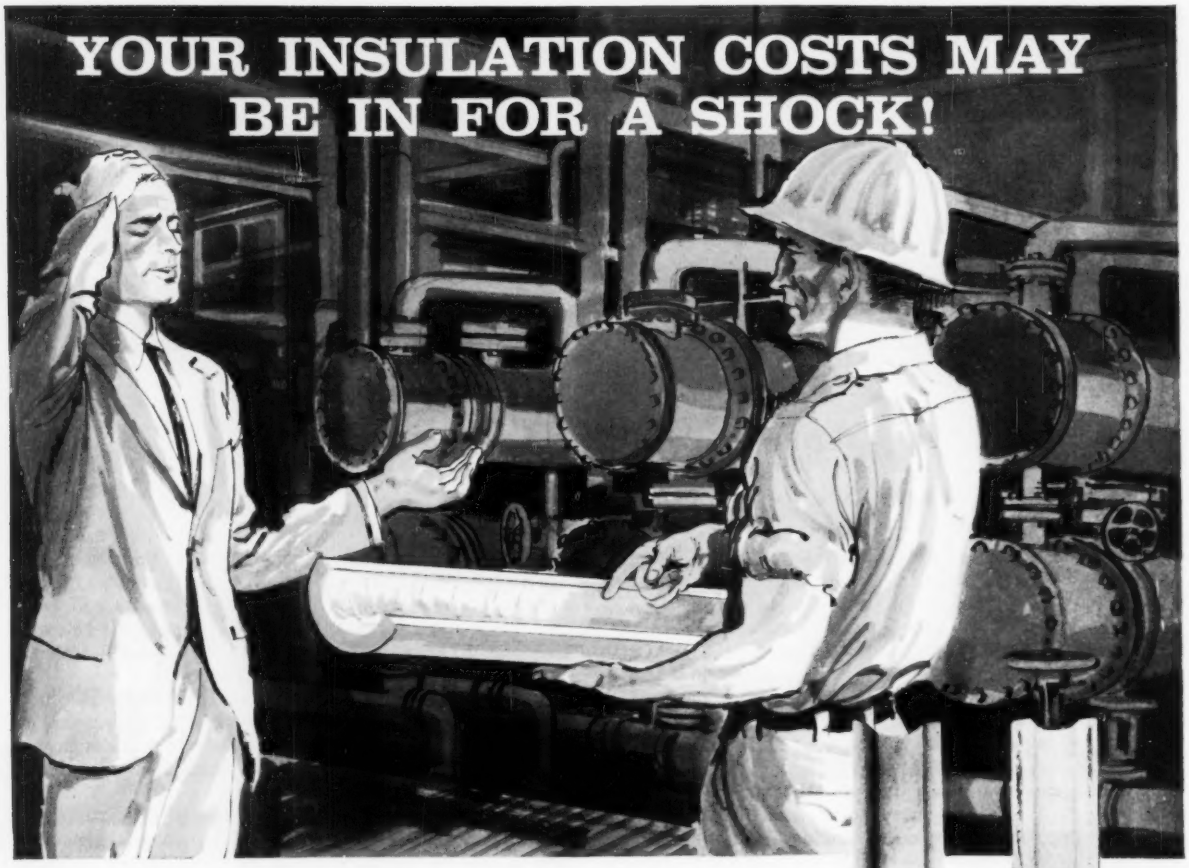


Saturn T-1000 dimensions

SOLAR
AIRCRAFT COMPANY
A subsidiary of International Harvester Company

For more data on advertised products, use Readers' Service Cards, last page.

YOUR INSULATION COSTS MAY BE IN FOR A SHOCK!



use Unibestos to eliminate thermal shock effects

Insulation that looks perfectly intact on the outside is sometimes a maze of cracks on the inside. That's when your operating costs, in the form of *heat losses*, begin sailing off into thin air. And it's thermal shock effects like this that can put the real shocker on your operating costs.

But you won't find thermal shock effects in any section of Unibestos insulation. Unibestos defies thermal shock, fumes, acids and moisture; resists impact and rough handling; eliminates shrinkage; cuts application time and costs; and guarantees real insulating efficiency. That's why it's worth more. Yet it continues to sell at competitive prices.

Available in full range of standard pipe sizes and thicknesses. Single thicknesses to five inches. Specials to 44″ O.D. in half sections.

Write today, on your letterhead, for Bulletin No. 65610.

UNIBESTOS AMOSITE INSULATION 900° F.

EFFECTS OF THERMAL SHOCK

Exclusive use of extra long *Amosite* asbestos is your positive assurance that Unibestos insulation has the mechanical qualities that prevent thermal shock effects. Guaranteed up to 1200° F, Unibestos has been known to withstand temperatures as high as 2000°F, without thermal shock effects.

UNIBESTOS

worth more, yet sold at competitive prices

UNARCO®

UNARCO PRODUCTS

• UNIBESTOS, Amosite Asbestos Pipe Covering and Block • Calcium Silicate Pipe Covering and Block • 85% Magnesia Pipe Covering and Block • Mineral Fiber Block • Wrap-On Insulation • Lace-On Insulation • Turbine Blankets • Insulating and Finishing Cements • Asbestos Textiles • Packing and Gasketing.

UNION ASBESTOS AND RUBBER COMPANY • FIBROUS PRODUCTS DIVISION

DEPT. 265, Bloomington, Illinois

Kerotest Keeps the PRESSURE ON for Quality

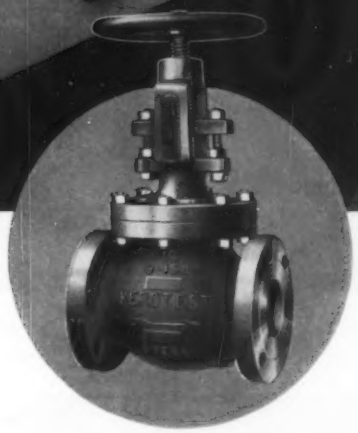
Before any Kerotest cast steel globe valve goes on stream, it's tested and approved in this final three-phase hydrostatic test. Here, with valve open and flanges blanked, the shell is subjected to maximum specified water pressure. The valve disc is then closed and the seat seal is checked hydrostatically and by air.

This testing stand adjacent to the production line is but one of the many quality control procedures employed at Kerotest to insure soundness of castings, seat seals and other operating parts. What's more, Kerotest's advanced design features bring you more precise flow control and regulation, reduce maintenance to a new low and assure longer valve life in all types of applications.

Kerotest Cast Steel Globe Valves

High quality Kerotest cast steel globe valves are available in primary service pressure ratings ranging from Series 150 to Series 1500. They are supplied in various combinations of body and trim material for all types of service in oil, gas, steam, water, chemical, petro-chemical, marine and industrial installations.

Send for your free copy of the new, informative Kerotest booklet. It's packed with working tables, dimensions, specifications and other helpful information.



KEROTEST
Quality Controlled Features

- Reinforced sections protect against unusual line strains, erosion and corrosion.
- Built for repacking under pressure in the full open position.
- Deep stuffing box for greater packing life and tighter seal.
- Threaded shoulder seating type seat rings replace without removing valve body from line.

There is a Kerotest Cast Steel Valve available for every class and condition of service.

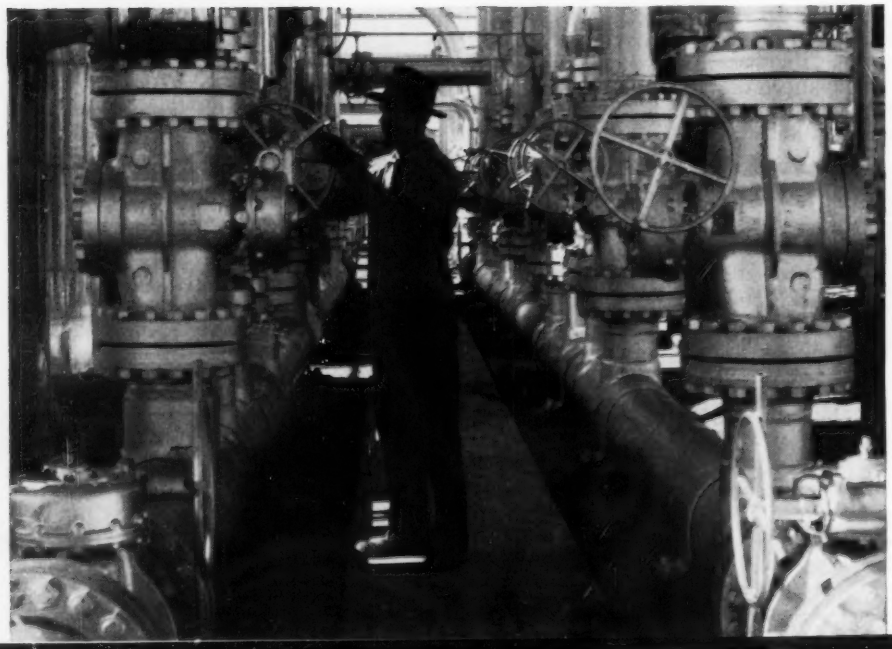
KEROTEST MANUFACTURING COMPANY

2514 LIBERTY AVENUE • PITTSBURGH 22, PA.

In Canada . . . Kerotest Cast Steel Valves are manufactured and distributed exclusively by Guelph Engineering Company, Guelph, Ontario, Canada

KEROTEST®

Rolling-in Republic ELECTRUNITE® Heat Exchanger Tubing.
Photo courtesy C. F. Braun & Company, Alhambra, California.



REPUBLIC ALLOY STEEL STUDS AND HIGH CARBON HEX NUTS provide the strength needed in high pressure equipment. High tensile strength with tough threads offer maximum holding power and resistance to wear. Tighten smoothly, back-off easily. Send for additional information.

FARROWTESTED FOR YOU...

REPUBLIC ELECTRUNITE HEAT EXCHANGER TUBES

Predictable, dependable service is measured for you when you specify FARROWTESTED Republic ELECTRUNITE Heat Exchanger Tubing—in either carbon or stainless steels. And, FARROWTEST is offered as an alternative to other less positive tests at no increase in cost!

FARROWTEST is Republic's exclusive non-destructive eddy-current test that probes for and detects injurious defects so small they pass ordinary internal fluid or gas pressure tests. FARROWTEST looks deep within the tube wall, is calibrated to reject tube with defects as shown in the table, below.

Republic ELECTRUNITE Heat Exchanger Tubing, in carbon steel, is produced to ASTM specification A-214. ELECTRUNITE Stainless Steel Heat Exchanger Tubing is produced to ASTM specification A-249. Both specifications include eddy-current requirements —FARROWTEST.

When ordering new equipment or retubing present units, investigate the advantages and economies of FARROWTESTED Republic ELECTRUNITE Heat Exchanger Tubing. Call your Republic representative, or send the convenient coupon below.

FARROWTEST REJECT TABLE

Wall Thickness (B.W. Gage)	Minor Dimension of Defect (Length or Depth)	Defective Area (Length, Depth Plane)
20	0.006 IN.	0.0025 Square Inches
18	0.006 IN.	0.003 Square Inches
16	12.5% of Wall	0.003 Square Inches
14 and 13	12.5% of Wall	0.004 Square Inches
12 and Heavier	12.5% of Wall	0.005 Square Inches

FARROWTEST detects and rejects not only tubing containing defects which completely penetrate the wall; but also tubing with defects equal to, or greater than, those shown in this table. For irregular defect shapes, a tube with defect area equal to or greater than shown above is rejectable. Where required, sensitivity of FARROWTEST equipment can be calibrated to reject defects of lesser specified area than shown in table, at extra cost.

FARROWTEST—QUALITY MEASURED FOR YOU. Not a laboratory theory, not a mere inspection tool, but an exclusive production test that detects and rejects tubing containing defects of critical size. FARROWTEST is offered as an alternative to other less positive tests in accordance with the table above, at no extra cost.

GET SAFE, SURE, DEPENDABLE shipping with Republic Steel Containers. Full range of barrels, drums, and pails in many styles and sizes up to 55 gallons capacity. Available plain, lacquered, or decorated. Write for a Republic Container Catalog.

REPUBLIC STEEL

World's Widest Range of Standard Steels and Steel Products

REPUBLIC STEEL CORPORATION
DEPT. PR-9887
1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Please send more information on the following products:

- ☐ Republic ELECTRUNITE Heat Exchanger Tubing—Carbon
- ☐ ELECTRUNITE Stainless Steel Heat Exchanger Tubing
- ☐ Republic Alloy Studs and High Carbon Hex Nuts
- ☐ Republic Containers Catalog ☐ FARROWTEST® Brochure

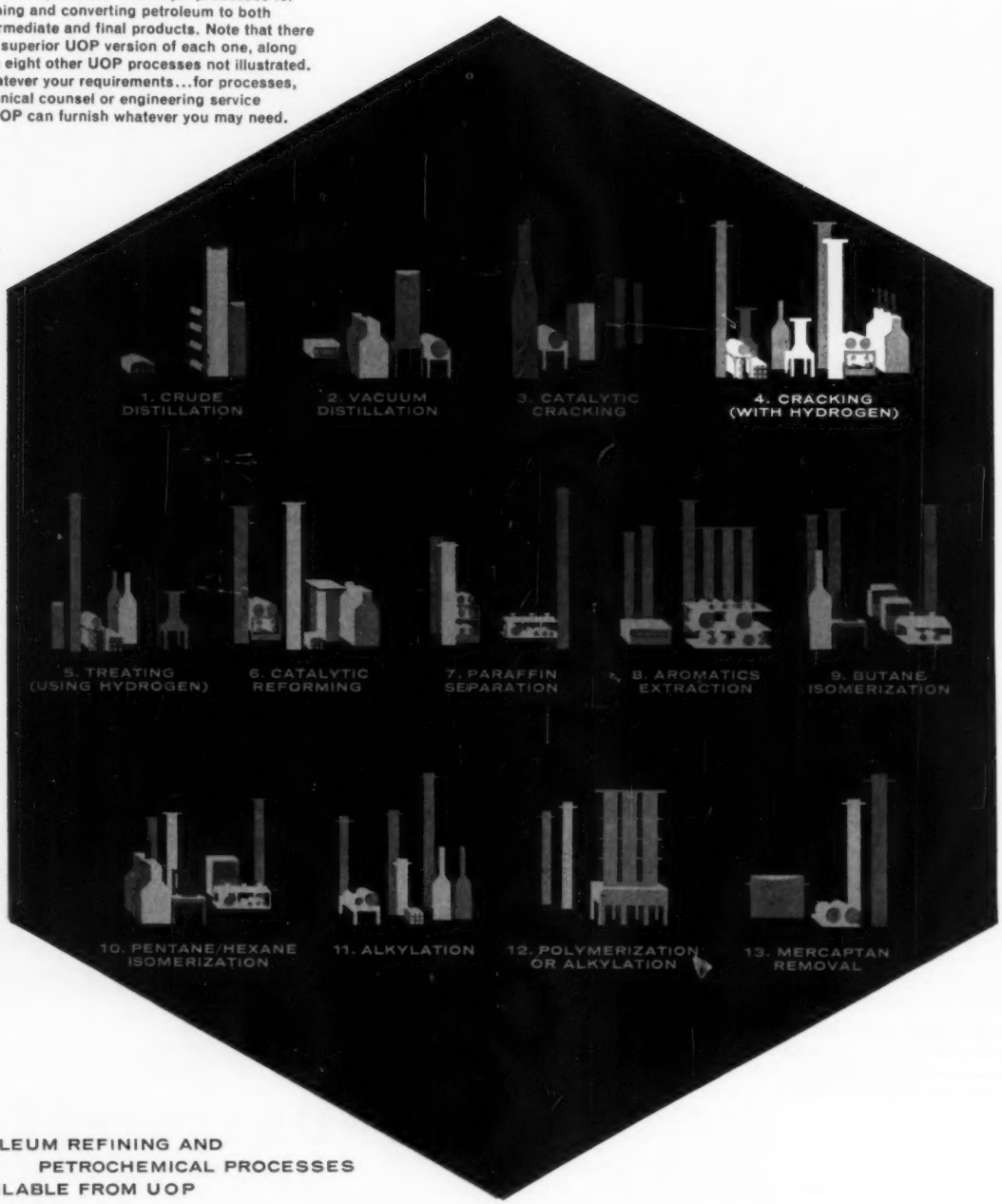
Name_____ Title_____

Firm_____

Address_____

City_____ Zone____ State_____

Here are symbolized the major processes for refining and converting petroleum to both intermediate and final products. Note that there is a superior UOP version of each one, along with eight other UOP processes not illustrated. Whatever your requirements...for processes, technical counsel or engineering service ...UOP can furnish whatever you may need.



PETROLEUM REFINING AND PETROCHEMICAL PROCESSES AVAILABLE FROM UOP

1. CRUDE DISTILLATION equipment is designed and engineered by UOP in any desired capacity.

2. VACUUM DISTILLATION and **VISBREAKING**—easy-to-operate processes for preparation of feed stocks for catalytic cracking.

3. FLUID CATALYTIC CRACKING—an improved process that gives higher yields, higher octane numbers.

4. LOMAX™—highly flexible process that converts middle distillates and vacuum gas oils into gasolines and distillate fuels of outstanding quality.

5. UNIFINING™—a modern process that completely purifies petroleum distillates.

6. PLATFORMING® produces high octane gasolines, high purity aromatics.

7. MOLEX™—a new continuous separating process that removes lowest-grade hydrocarbons from gasoline.

8. UDEX®—the ideal process for separation of super-purity aromatics.

9. BUTAMER™—a new and practical process for producing isobutane.

10. PENEX®—a new process that converts light, normal paraffins to isoparaffins.

11. HF ALKYLATION—makes alkylate, top anti-rumble motor fuel. Sulfuric acid process also available.

12. CATALYTIC CONDENSATION—converts olefin fractions of refinery gases into high-quality gasoline and petrochemicals.

13. MEROX™—a new and inexpensive treating process to remove mercaptans from gasolines and light distillates.

PROCESSES NOT ILLUSTRATED:

REFORMING®—the ideal process to insure your top octane position.

CATALYTIC DEHYDROGENATION—removes hydrogen from hydrocarbons to produce less-saturated hydrocarbons.

HYDEAL™—a new process for the hydrodealkylation of toluene or C_8 aromatics to produce benzene; may also be used for manufacturing phenol and naphthalene.

HYDRAR™—converts benzene to cyclohexane with excellent yields, achieves extreme high purity with Udex grade benzene.

OLEFIN EXTRACTION—efficiently separates olefins and diolefins from paraffins; prepares olefins for further conversion.

AROSORB™—removes heavier aromatics from synthetic and natural distillates, produces aromatic-free heavier distillates.

ALKAR™—produces ethylbenzene, cumene and other alkylated aromatics from Fluid Cat Cracker off-gas streams.

UNISOL®—an economical process for treating high mercaptan-containing gasolines.

For more data on advertised products, use Readers' Service Cards, last page.

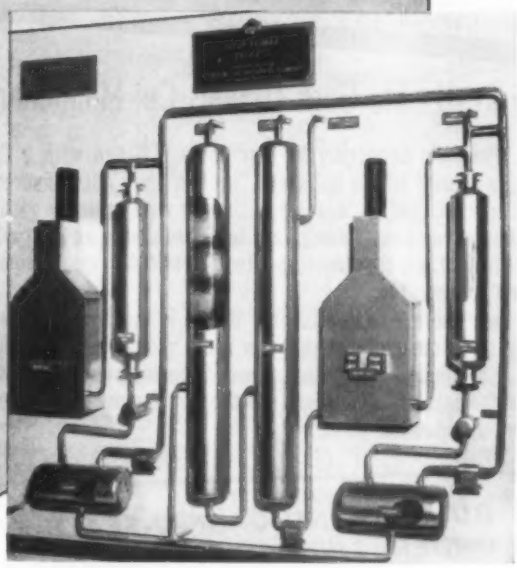
'62 COULD BE THE YEAR FOR YOU!

how to make products your customers want to buy...

Described below is the new and versatile UOP process . . . LOMAX. A remarkable and ultra-flexible cracking-with-hydrogen process, LOMAX enables the refiner to reach a new high in operating flexibility. He can convert his middle distillates into the most *immediately saleable* ratio of gasoline and distillate fuels . . . and change his ratio to fit the changing needs of his market.

With UOP processes the refiner can accomplish just about anything that comes within the realm of practical petroleum refining technology. Take a look at the brief descriptions on the opposite page, and you'll agree. And remember, in many cases existing equipment can be revamped and expanded, and thereby will produce more saleable products.

*INFORMED OPINION indicates that 1962 will require a substantial increase in process capacity ...NOW is the time to start your planning! Ask us about a preliminary proposal... no obligation!



LOMAX™ With this new and highly flexible UOP process, model of which is shown above, the refiner is able to increase production of his most currently saleable product on a year-'round basis. Through the catalyzed reaction of oil with hydrogen, LOMAX converts middle distillates ranging from kerosines to heavy gas oils into a wide ratio of gasoline or distillate fuels.

As seasonal demands change, LOMAX production of these products is adjusted accordingly.

Important additional benefits afforded by LOMAX include distillates of exceptionally high purity (even from sour crudes) . . . predominance of branched isomers in light hydrocarbons . . . greatly reduced quantities of light gases . . . olefin-free products . . . long catalyst life . . . and other advantages.

LOMAX may be used to supplement existing facilities, or as a basic cracking operation in a new installation.

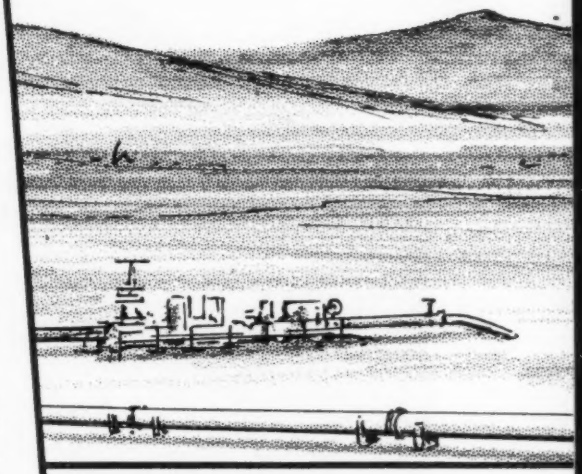
UOP®

UNIVERSAL OIL PRODUCTS COMPANY

30 Algonquin Road, Des Plaines, Illinois, U.S.A.

WHERE RESEARCH TODAY MEANS PROGRESS TOMORROW

World's Largest LPG Pipe



WILLIAMS BROTHERS COMPANY SPECIFY NEW BLOWOUT-PROOF GASKETS AS FLANGE SEAL FOR MID AMERICA'S 2,200 MILE PIPE LINE.

Engineers for Mid America Pipe Line Company, had to have a flange seal to meet some of the toughest specifications in pipe line construction. They wanted the best. They wanted a gasket with maximum effectiveness,(leakage rate equivalent to welding!) easy installation, long service life, and low maintenance cost.

After exhaustive tests and investigation they chose Gask-O-Seals. Said Williams Brothers engineers, "Primarily we had to have a seal that was blow-out proof. The controlled confinement principle used in Gask-O-Seals proved exactly what we wanted."

Several thousands of these amazing gaskets seal main line and subsidiary equipment on this 2,200 mile high pressure system — the longest and largest LPG line ever built. It runs from New Mexico and Texas, to Minnesota and Wisconsin. The line and its complexes will serve millions of customers providing low cost and better service with Propane, Butane and natural gasoline.

Re-Usable Gask-O-Seals Cut Maintenance Cost

When it's necessary to tear down a flange with a Gask-O-Seal in it the ease with which bolts are "broken" and nuts unscrewed is a revelation to men used to "cracking" flanges with ordinary gaskets. The reason is simple, you simply don't have to tighten bolts as tight with Gask-O-Seals . . . in fact, on construction sites for Mid-America's pipe line you never saw a "cheater!"

Even more amazing to pipe fitters is the fact that flange faces don't have to be cleaned and that the same gasket can actually be reinstalled!

The reduced maintenance cost mounts up to a really big saving when Gask-O-Seals are specified, whether in a pipe line, refinery, processing plant, or industrial plant.

WHY GASK-O-SEALS ARE SO EFFECTIVE--

Gask-O-Seals are effective because of the sealing principle involved . . . controlled confinement. That means that the "rubber" mass to groove void is carefully controlled. The gland is totally confined with metal-to-metal contact of faying surfaces. The whole seal is designed and manufactured to carefully controlled tolerances. The Gask-O-Seal design allows very, very little area of attack on the seal itself by the materials being sealed.

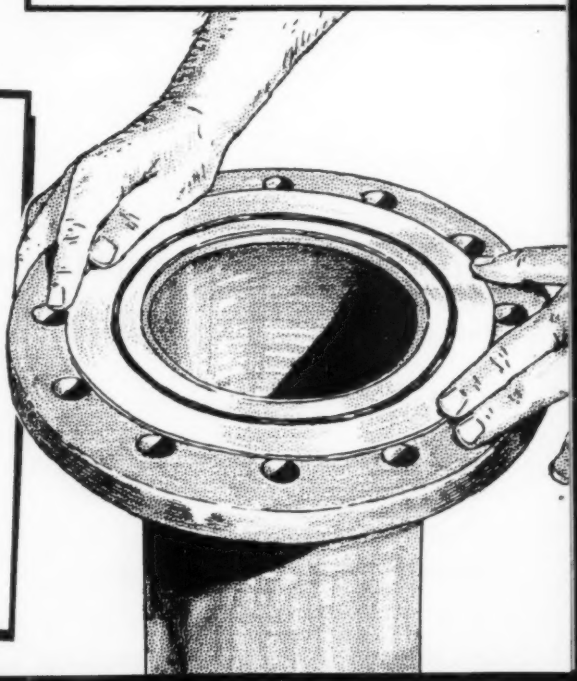
Of course, there are many other features about the Gask-O-Seal that makes it unique as an effective, safe, sure seal. Some of them quite technical, others just common-sense reasons. The fact that they are used in so many vital apparatuses attests to their superior sealing effectiveness.

BUYERS FIND GASK-O-SEALS EASY TO ORDER—PRAISE DISTRIBUTION METHOD

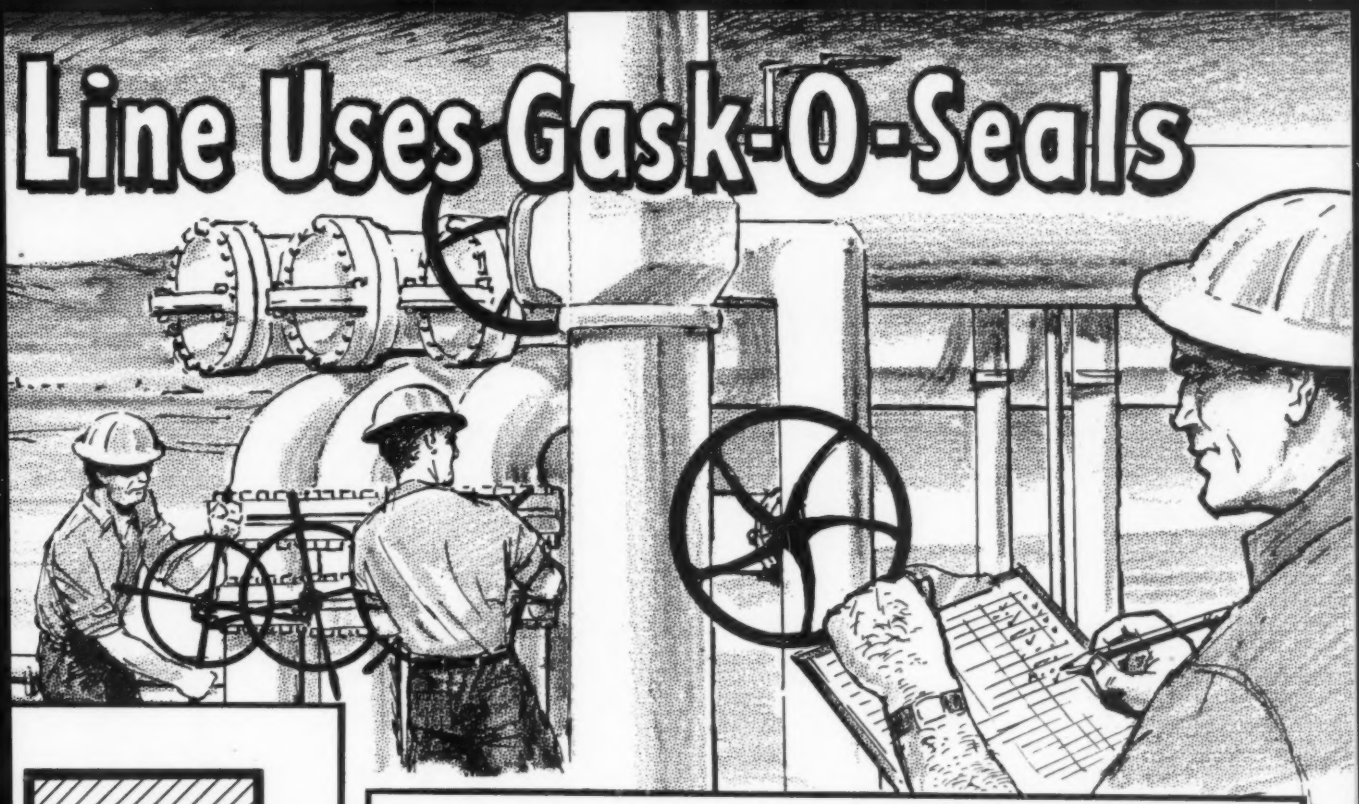
Industrial buyers find that Gask-O-Seals are readily available and easy to order with a simplified "call out" system, tieing into standard ASA flange sizes and specifications.

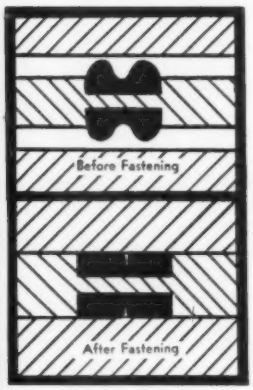
In addition buyers preferring local sources usually find a Parker Seal Company stocking distributor close by. More and more distributors are requesting franchises as preference for Gask-O-Seals grows.

"Many of these distributors are recommended to us by purchasing men as well as engineers," says Mr. T. J. McCuistion, Vice-president in charge of sales at Parker. "Such recommendations are very much appreciated. The company will gladly consider the request of any qualified distributor for a franchise on this new product line."



Line Uses Gask-O-Seals





Underwriter's Lab Tests Gask-O-Seals, Approve For Listing

LISTED UNDER REEXAMINATION SERVICE UL OF UNDERWRITERS' LABORATORIES, INC.

To be sure that customers could have confidence in the competitive safety of Gask-O-Seals, Parker Seal Company submitted all of standard ASA flange series seals to Underwriter's Laboratories for testing. They have approved all four of the series 6400, 6420, 6430, and 6440 for listing under their re-examination code, and granted permission to use their insignia for the services covered.

HOW TO SAVE *19 MINUTES* EVERY TIME YOU "BREAK" A FLANGE!

A testing foreman on Mid-America's pipe line saw Williams Brothers men installing Gask-O-Seals in flanges at the Conway, Kansas, Terminal. He turned to the Parker Seal Co. representative standing nearby and said:

"Man, go see my boss about those gaskets. I'm saving hours and plenty of money with them. We can just put 'em in for a test, break up and move, and *re-use the same gasket, over and over again!*"

A maintenance foreman said Gask-O-Seals may save them "2 days time of two 4 man crews-with trucks, wenches and other equipment."

A survey shows it takes an average of 36 minutes to remove and install an ordinary gasket after several months use. With Gask-O-Seal it takes only 17 minutes! Here's how it breaks down:

3 minutes saved in "breaking" nuts, 3 minutes saved in parting flanges to necessary working space, 13 minutes in not having to clean and scrape flange faces — and you can install the same Gask-O-Seals you take out!

A worthwhile saving?

OVER 1,000,000 GASK-O-SEALS USED UNDER THE VERY TOUGHEST CONDITIONS BY AIRCRAFT AND MISSILES.

The sealing effectiveness and high safety factor of Gask-O-Seals were first recognized by the aircraft and missile makers to whom, safety, and genuine effectiveness of a seal is paramount.

Hundreds of tests have been run on Gask-O-Seals under some of the most rugged functional and environmental specifications a seal can undergo.

Today, Gask-O-Seals—much the same as the ones used on Mid America's new pipe line—are in use on practically every military and commercial aircraft. A Gask-O-Seal, for instance, seals the escape hatch and other openings of the Mercury capsule on the "man-in-space" project.

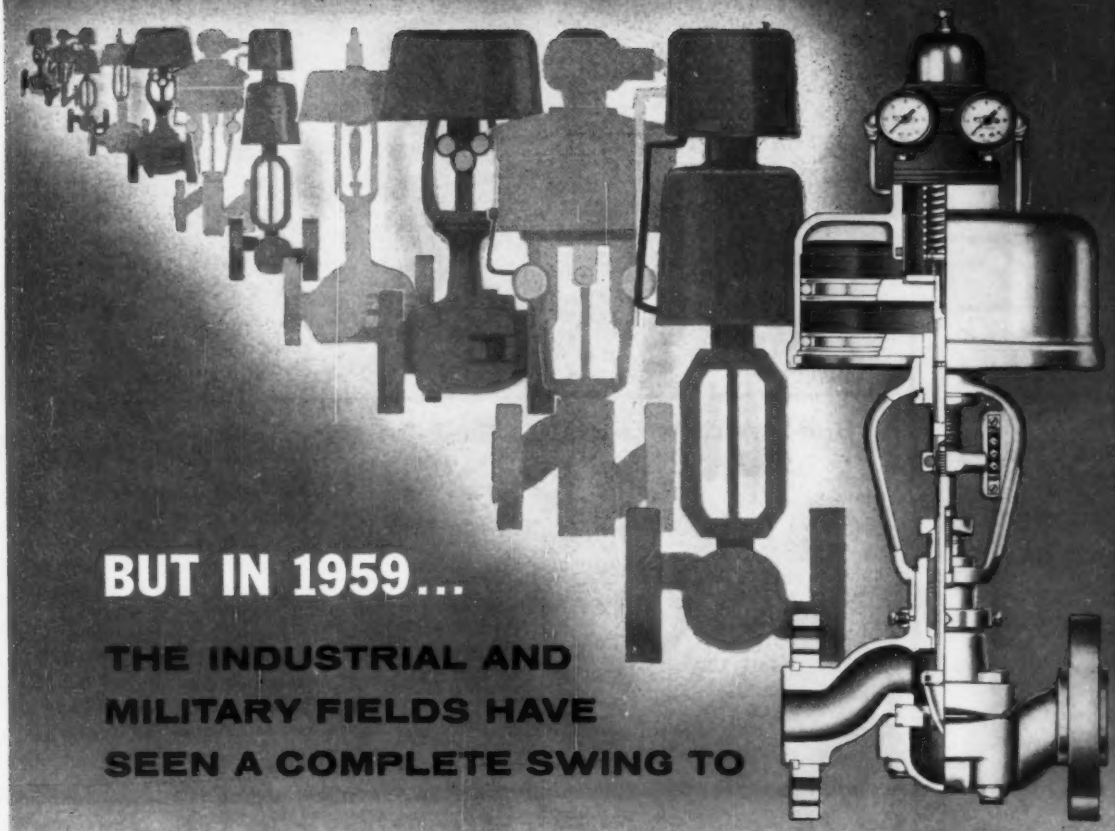
Parker SEAL COMPANY

Culver City, California and Cleveland, Ohio

A DIVISION OF PARKER-HANNIFIN CORPORATION

IN 1948...THEY SAID IT COULDN'T BE DONE

...that split body, single seat construction would never be the accepted design for industrial or military control valves.



BUT IN 1959...

THE INDUSTRIAL AND MILITARY FIELDS HAVE SEEN A COMPLETE SWING TO

CONTROL the ANNIN WAY

In 1948 split body construction and powerful high speed, precise positioning pneumatic piston actuators were available from only one source—Annin. Today, more than a decade of accumulated experience in this type of valve design makes Annin features and performance records the best in the valve industry. Contrary to published statements by critics ten years ago, Annin-type construction is now available from many sources. But when tempted to consider *mere-replicas* of Annin valves, remember this—they might give you a few Annin features, but when you specify Annin Valves you get them all!

Annin VALVES

THE ANNIN COMPANY
1040 South Vail Avenue
Montebello, California

A worthwhile saving.

HARBISON-WALKER REFRACTORIES

for maximum durability in all petroleum refining and petrochemical applications

Harbison-Walker manufactures all the different kinds of commercial refractories. From these are selected those which best withstand the severe destructive factors of corrosion, abrasion and reducing atmospheres and consequently provide the greatest economy.

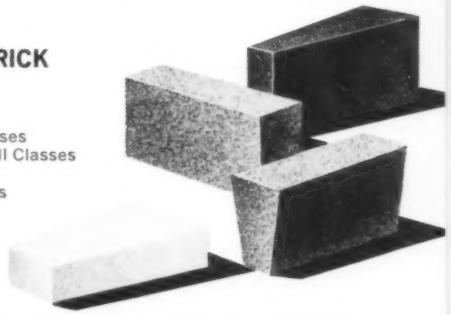
Headquarters of refractories progress
Garber Research Center

MONOLITHIC REFRACTORIES

Castables, All Classes
Plastic Fire Brick, All Classes
Special Gun Mixes
Trowelling Mixes
Ramming Mixes

REFRACTORY BRICK AND SHAPES

Fireclay Brick, All Classes
High-Alumina Brick, All Classes
Silica Brick
Basic Brick, All Classes
Acid-Proof Brick
Zircon Brick
Silicon Carbide Brick

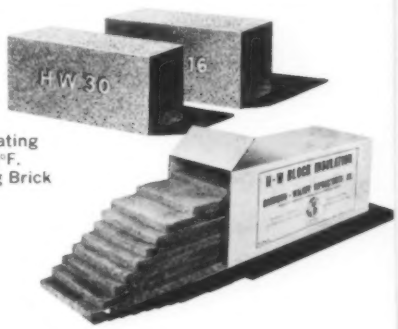


MORTARS AND GRANULAR MATERIALS

High Temperature Bonding Mortars
Complete range of compositions
Both Heat-Set and Air-Set, ready mixed and dry Fireclays—Special Clays
Ganister

INSULATING REFRACTORIES

Includes All Classes of Insulating Firebrick—1600°F. to 3000°F.
Mortars for Laying Insulating Brick
H-W Lightweight Castables
H-W Block Insulation
H-W Finishing Cement
H-W Mineral Fiber Coating

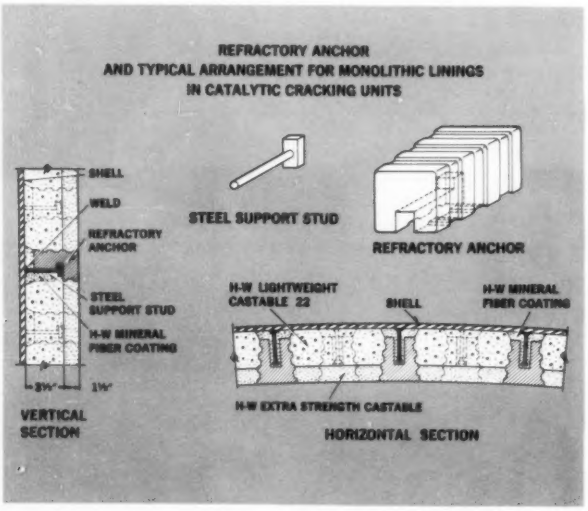


H-W CASTABLE REFRACTORIES

FOR THE SPECIAL REQUIREMENTS OF THE OIL REFINING AND PETROCHEMICAL INDUSTRIES

BRAND	APPROXIMATE SERVICE LIMIT	PROPERTIES	TYPICAL APPLICATIONS
H-W EXTRA STRENGTH CASTABLE	2400°F.	Unusually high strength and resistance to abrasion. The strongest by a wide margin, among all the regular castables. May be poured or gunned. 114 lbs. of dry material required per cu. ft. of construction.	Lining catalytic cracking vessels and catalyst feed lines, doors and sub-bottoms of various types of furnaces, patching worn brickwork and for coating interior walls of furnaces.
H-W HARCHROME AND H-W HARCHROME G	2600°F.	High strength and resistance to abrasion. 166 lbs. of dry material required per cu. ft. of construction.	For lining cyclones and feed lines in catalyst units.
H-W CASTOLAST AND H-W CASTOLAST G	3200°F.	An extremely high purity low-iron refractory concrete consisting of accurately sized tabular alumina, blended with low-iron calcium-aluminate binder. Develops high strength and is highly resistant to corrosive gases and reducing atmospheres. 143 lbs. of dry material required per cu. ft. of construction.	Linings for Butadiene reactors, reformer vessels, hot cyclones and catalyst feed lines, and for high temperature burner blocks.
H-W HARCAST and H-W HARCAST GT	2800°F.	Highly resistant to reducing conditions with a ferric oxide content of less than 0.5% which adequately meets the specifications of petroleum companies. For use where platinum catalysts are employed. Exceptional strength at all temperatures up to its service limit. 123 lbs. of dry material required per cu. ft. of construction.	For severe erosion areas such as regenerator cyclones and catalyst feed lines.
H-W LIGHTWEIGHT CASTABLE 22 (Former brand name—H-W 56 Lightweight Castable)	2200°F.	Combines light weight and strength to the utmost degree. Has thermal conductivity of approximately 35% of that of fire brick. 50 lbs. of dry material required per cu. ft. of construction.	Refinery vessel linings, ducts and breechings, boiler wall backing and tube decks, air preheater linings, furnace walls, roofs and doors.
H-W LOW-IRON LIGHTWEIGHT CASTABLE 22 (Former brand name—H-W 56 Low-Iron Lightweight Castable)	2200°F.	Has exceptionally low ferric oxide content of less than 0.5%. Excellent strength. 50 lbs. of dry material required per cu. ft. of construction.	Refinery vessel linings where material must meet low iron specifications.
H-W CC LIGHTWEIGHT CASTABLE	2300°F.	Combines light weight and high strength, low heat conductivity and desirable refractoriness. 85 lbs. of dry material required per cu. ft. of construction.	Oil refinery units, one shot linings, ducts and breeching, boiler wall backing and tube decks, furnace walls, roofs and doors.

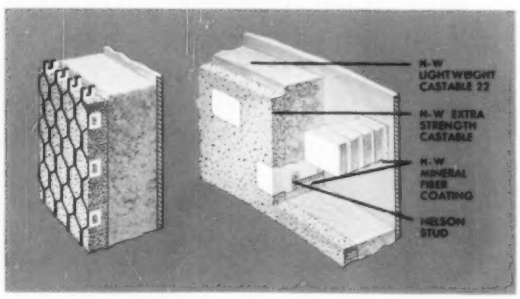
Weights shown are approximate, based on casting in place, and for gun applications are slightly higher.



CASTABLE CONSTRUCTION FOR REFINERIES

(Left) Illustration shows H-W Lightweight (Insulating) Castable 22 next to the regenerator shell with H-W Extra Strength Castable superimposed in hex steel for working lining.

(Right) Typical arrangement of refractory anchor method for monolithic linings in catalytic cracking units. H-W Mineral Fiber Coating provides insulation for metal stud.



REFRACTORY BRICK

FIRECLAY REFRACTORIES

The various brands of Harbison-Walker fireclay brick meet the requirements for each individual class of refractory to the fullest extent. They have a wide range of physical properties, and possess utility for many different service requirements. Harbison-Walker fireclay brick are of the highest quality and workmanship and are widely regarded as standard for all kinds of furnace linings, and for all operating conditions for which fireclay brick are suited.

SUPERDUTY FIRECLAY REFRACTORIES

To meet the more exacting requirements of modern industrial furnaces, Harbison-Walker has developed brands of brick of the superduty fireclay type, namely, ALAMO, VARNON, BOONE, H-W SUPER-SAVAGE, KENMORE, H-W KALA, ZENITH and DEAN. These are superior to high-duty fireclay brick in refractoriness and most of the other important physical properties and in chemical composition.

HIGH-ALUMINA REFRACTORIES

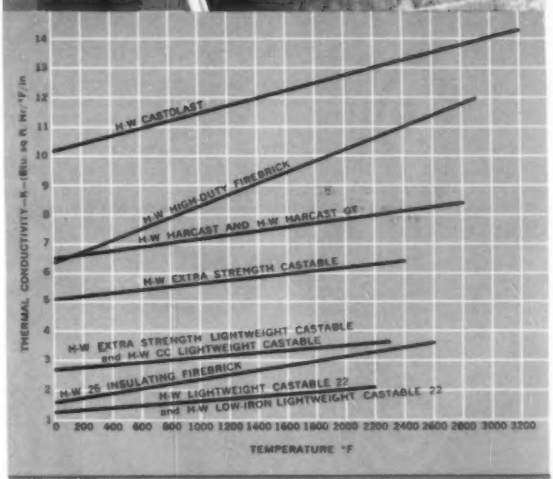
Harbison-Walker high-alumina brands include all the commercial classes from 50% to 99% alumina. In certain of these brands the desired properties are obtained by using as raw material, the highest grades of diaspore clay or other aluminous minerals. In others, use is made of blends containing crystalline alumina or corundum. In each case, during manufacture, the brick are subjected to the particular heat treatment which will effect the most desirable mineral conversions to mullite and corundum. High-alumina brick of all the various classes are more refractory and more resistant to the corrosive action of vanadium oxide and alkalies of oil ash than are fireclay or kaolin brick, approximately in proportion to their content of alumina.

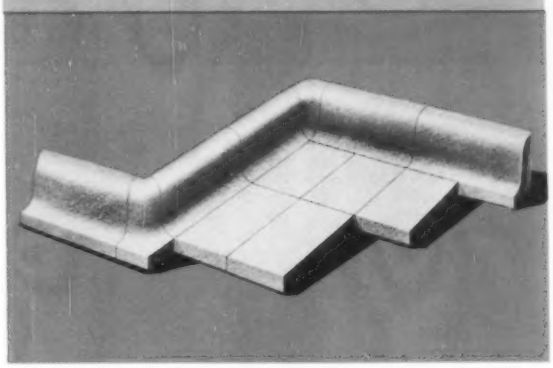
ACID-PROOF BRICK, SHAPES AND PACKING TILE

DURO and W-ACID acid-proof brick and tile are dense, vitreous and non-absorbent. They are strongly resistant to the action of all mineral acids, except hydrofluoric, as well as to organic acids and many other solvents. The properties of low porosity, with the resultant non-absorbent quality and high strength are imparted by the controlled quality of raw material, the method of manufacture and by the high temperature at which they are fired. The refractoriness is unusually high for acid-resisting materials. These brands of brick are well adapted for service in processes using temperatures as high as 2300°F. in conjunction with nascent gases and acid fumes. They have exceptionally high mechanical strength.

DURO and W-ACID are considered standard in many industrial plants for floors where acid spillage, hard wear, continued dampness or other detrimental conditions prevail. The standard 12 x 6 x 1½" or 9 x 4½ x 1½" tile are used most widely for this application.

DURO tower packing, including the 12 x 6 x 1½" tile, rings and the grid tile, are exceedingly durable and highly efficient.


THERMAL CONDUCTIVITY—K—(Btu in sq ft, hr/°F in
H-W CASTOLAST
H-W HIGH-DUTY FIREBRICK
H-W HARCAST AND H-W HARCAST QT
H-W EXTRA STRENGTH CASTABLE
H-W EXTRA STRENGTH LIGHTWEIGHT CASTABLE and H-W CC LIGHTWEIGHT CASTABLE
H-W 25 INSULATING FIREBRICK
H-W LIGHTWEIGHT CASTABLE 22 and H-W LOW-IRON LIGHTWEIGHT CASTABLE 22
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200
TEMPERATURE °F



DURO ACID-PROOF FLOOR TILE

Duro Floor Tile are strong and withstand wear. They are dense, non-absorbent, and impervious to acids and other corrosive chemicals.

MORTARS, AIR-SETTING and HEAT-SETTING

For any refractory fire brick construction the selection of the most suitable bonding mortar is as important as is the selection of the most suitable brick. The choice depends upon the service requirements, and the mortar selected should be compatible in refractoriness and other properties, with those of the refractory brick.

HARWACO BOND is an air-setting high temperature bonding mortar which is shipped in the wet form, ready mixed for use. Experience in the use of this mortar has proved the excellence of its workability. HARWACO BOND is recommended for use in laying fireclay, superduty fireclay and high-alumina brick. In some applications it is used to advantage for laying SILICON CARBIDE brick.

PENSEAL is an air-setting high temperature bonding mortar having unusual plasticity. It is shipped ready mixed in steel drums of 100 and 200 pound net weights. Because of its intermediate refractoriness, PENSEAL is used where dense vitreous joints and coatings are especially desirable.

THERMOLITH is a highly refractory air-setting bonding mortar in dry form. It consists of finely ground chrome of the best quality and uniformity, combined with chemical binders and plasticizers. THERMOLITH is chemically neutral which accounts for its excellent resistance to corrosive slags and fumes of a wide range in chemical compositions.

ANKORITE 65 is a heat-setting high-alumina bonding mortar shipped in dry form. It is used to advantage under certain conditions for laying high-duty and superduty fireclay brick and high-alumina brick.

KORUNDAL BONDING MORTAR has extremely high refractoriness imparted by its alumina content of more than 85%. Its fusion point is in excess of 3300°F. and it is designed primarily for use with KORUNDAL brick and where extremely high refractoriness is required. It is an air-setting high temperature cement in the dry form.

CORALITE BONDING MORTAR is a strong air-setting high temperature cement with a high-alumina base. This material develops an extremely strong bond upon air-setting and is designed for use at very high temperatures. CORALITE BONDING MORTAR is shipped in the wet form in steel drums.

SPECIAL PURPOSE MORTARS. In addition to these high temperature mortars, Harbison-Walker produces others of a wide range in composition and physical properties. H-W CORUNDUM consists largely of crystalline alumina; FIREBOND is highly siliceous; H-W PERIKLASE is highly basic, consisting essentially of crystalline magnesia; and H-W FORSTERITE is the magnesium silicate mortar possessing unusual properties. These mortars are particularly adapted for specific applications.

HARWACO MASTIC is a plastic air-setting monolithic refractory which has a working consistency similar to that of stiff putty. It is ideally suited for plastering with a trowel, as for example, for sealing the V-shaped spaces at the exterior face of tangential tubes.

Others of major importance for their special purposes are Harbide Mortar (silicon carbide) and H-W Zircon mortar.

INSULATING REFRACTORIES

In the application of insulation to industrial furnace linings, a great many combinations of insulating fire brick and refractory fire brick are possible. Harbison-Walker, with complete lines of both insulating fire brick and refractory fire brick, can furnish the correct combination for all service requirements. Write for complete information.

Brand Name	H-W 16-20	H-W 20	H-W 23LI H-W 23	H-W 26	H-W 28	H-W 30	Vegalite
Maximum Temperature Limit	1600°F	2000°F	2300°F	2600°F	2800°F	3000°F	3000°F
Application	May be used as insulating backing for the more dense refractory brick of various types. In many cases they may be used also in place of refractory fire brick, directly exposed to furnace atmosphere, but not exposed to slagging action or severe mechanical abrasion.						
Selection of Brand	Any application of these insulating fire brick requires very careful consideration of furnace operating temperatures in relation to the maximum temperature limits given in this table. When insulating fire brick are used as backing for refractory fire brick, the maximum operating interface temperature that can prevail between the refractory lining and the insulation governs the choice.						

HARBISON-WALKER REFRACTORIES COMPANY and subsidiaries

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Agents and Dealers throughout United States, Canada and other countries.

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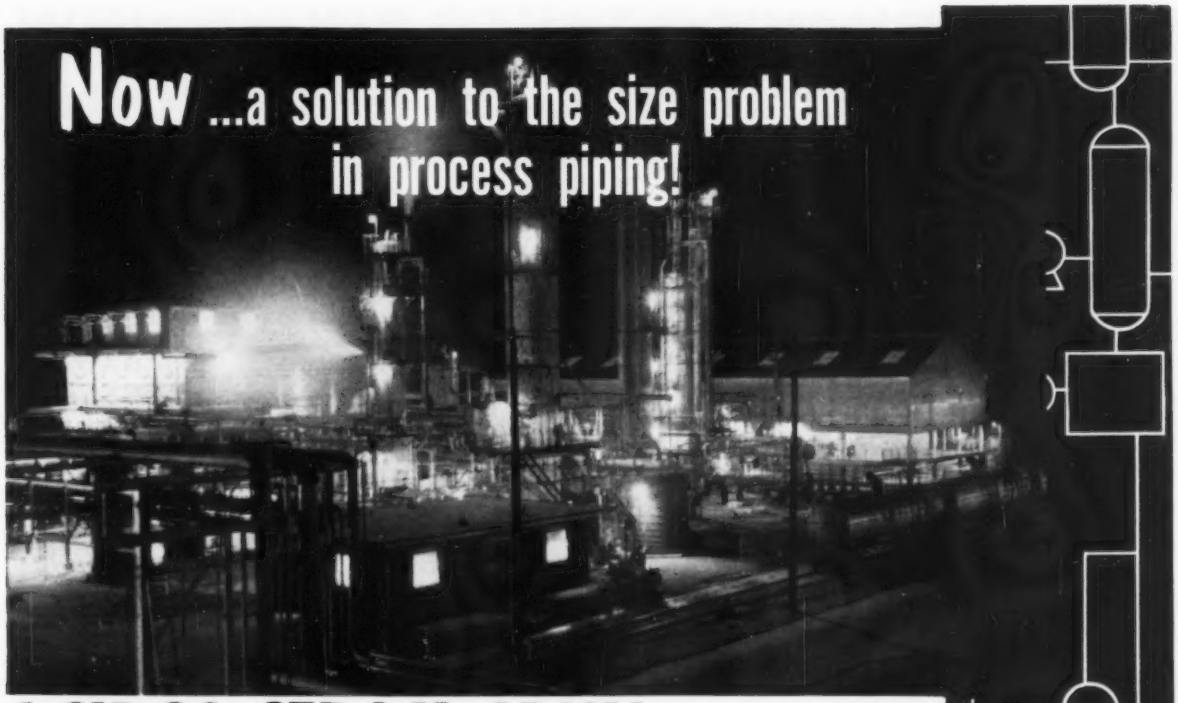
Now ...a solution to the size problem in process piping!



ACIPCO CERAM-SPUN STEEL TUBING

...offers a wider range of O.D.'s from 2.25" to 50"; wall thicknesses from .25" to 8"; lengths up to 20'.

Prompt procurement of tubular process piping for the refinery and petro-chemical industries has become a concern to design engineers as specified sizes have steadily progressed to larger diameters and heavier walls.

Now, size can be less of a problem . . . thanks to new ACIPCO CERAM-SPUN tubing. This revolutionary process has resulted in the availability of centrifugally spun process piping in practically every conceivable variation of diameter and thickness . . . and without costly tooling charges. Here is greater freedom in design . . . and increased savings.

Retorts, reformer and furnace tubes, heat exchangers, as well as many other pieces of equipment, have been fabricated from ACIPCO centrifugally spun tubing.

Investigate the advantages of ACIPCO CERAM-SPUN tubing. ACIPCO's complete facilities offer service from centrifugal or static castings to finished parts.

ASA Code for Pressure Piping — Petroleum Refinery Piping (ASA B 31.3-1959) authorizes the use of centrifugally spun stainless pipe made in compliance with ASTM Specification A426-58T. This specification is entitled, "Centrifugally Cast Ferritic Alloy Steel Pipe for High Temperature Service." Write for a free copy.

SIZE RANGES: Tubes are produced in lengths from 4' to 20'; longer lengths are made by welding. O.D.'s from 2.25" to 50" — wall thicknesses from .25" to 8".

ANALYSES: All alloy grades in steel and cast iron, including heat and corrosion resistant stainless steels, plain carbon steel and special non-standard analyses.

FINISHES: As cast, rough machined, or finished machined, including honing and grinding. Complete welding and machine shop facilities are available.

ACIPCO

SPECIAL PRODUCTS

DIVISION OF AMERICAN CAST IRON PIPE CO.

BIRMINGHAM · ALABAMA

For more data on advertised products, use Readers' Service Cards, last page.

COUNTRY-WIDE TESTS PROVE HOW TOTCO CONTINUOUS END-POINT ANALYZER CUTS CONTROL COSTS

...INCREASES YIELD *In major refineries from the East Coast to the West, the new Totco continuous End-Point Analyzer has demonstrated its ability to provide better control over product quality and yield. It quickly pays for itself and steps up profits.* ■ *This sensitive instrument continuously indicates the Engler End Point of a hydrocarbon stock or commodity in an operating range of 200° F. to 700° F. It delivers reproducibility within ±1°F., with results that correlate with ASTM D86 or ASTM D158. And its continuous analysis cuts the usual delays between quality change and compensating plant control... eliminates the time lag of batch analyzers or conventional laboratory tests.* ■ *Write or call today for further information. Request Bulletin 5900-11.*

CASE HISTORY #1

Major Eastern Refinery

Use of the TOTCO End-Point Analyzer enabled this refiner to step up end-point specifications of reformer feed stock by 10°F with safety. Result: increased yield and a saving of over $200 a day. On the basis of this test, six additional Totco units were ordered!

CASE HISTORY #2

Major West Coast Refinery

Both TOTCO's End-Point Analyzer and Initial Boiling Point Analyzer were used here on a narrow-cut solvent. It was found that the analyzers kept yield on grade better than 99% of the time! Previous average with laboratory control was 90%.

CASE HISTORY #3

Major Mid-West Refinery

In this test, the TOTCO End-Point Analyzer was mounted in a trailer and used on a crude still to control first-cut products on stream. So successful was the test that the company ordered two additional Analyzers for use at other refineries.

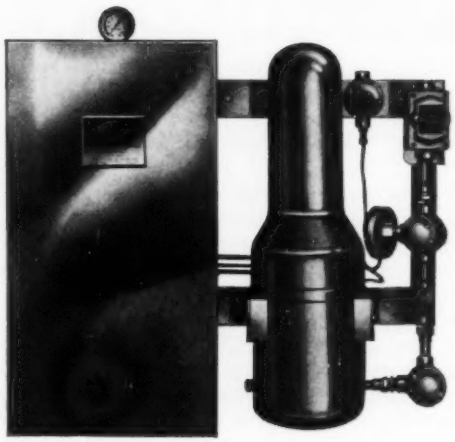
CASE HISTORY #4

Major Western Refinery

Demonstrating the versatility of the TOTCO End-Point Analyzer was this test where it was used to control the cut on heavy naptha. The test was a money-saving success, and the firm has since ordered additional units.

TOTCO CONTINUOUS INITIAL BOILING POINT ANALYZER

Totco also manufactures an Initial Boiling Point Analyzer. Write for Bulletin 1259-11 giving details and operating data.



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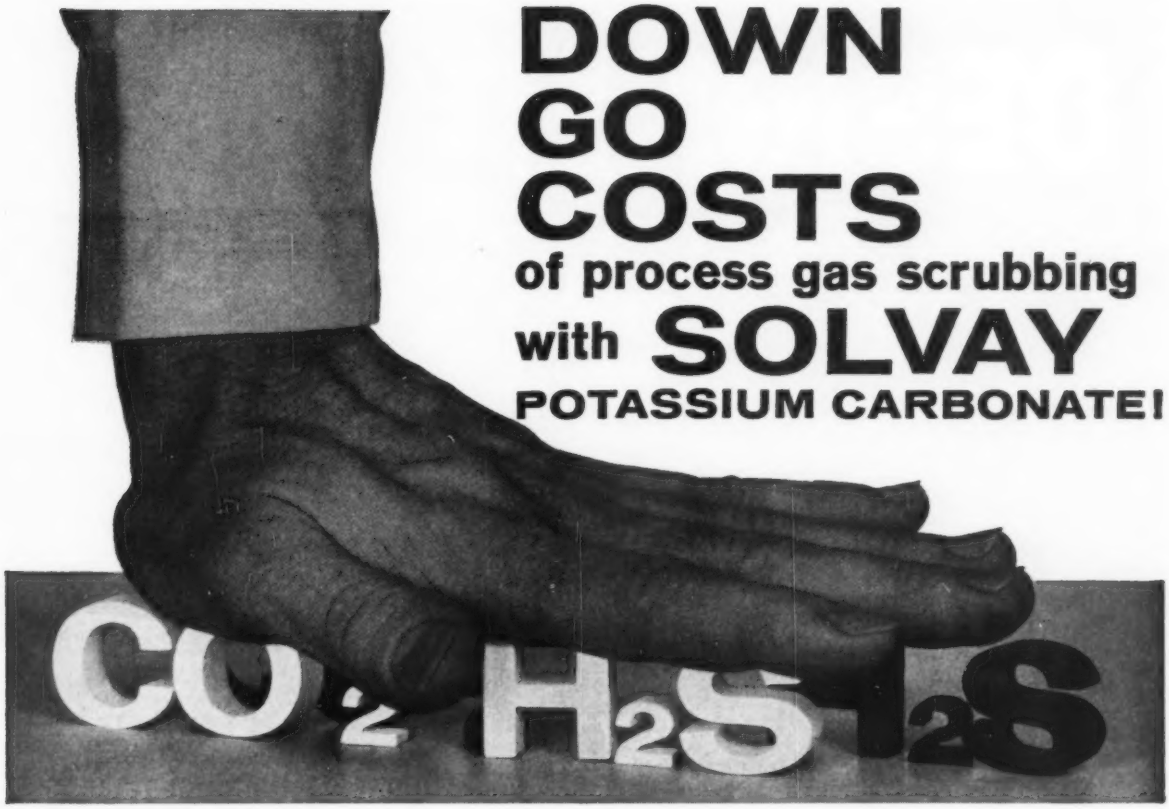

DOWN GO COSTS

of process gas scrubbing with SOLVAY POTASSIUM CARBONATE!

Save on utilities and fuel . . . purify process gases using the Hot Carbonate Process with Solvay® Potassium Carbonate. The hot circulating carbonate solution does away with costly heat exchangers and reduces steam requirements.

Wherever conditions of fairly high concentration and partial pressure exist, this is the most economical way to take out carbon dioxide from process gases. Applications range from ammonia synthesis to petrochemicals.

In natural gas treating, it is used to remove *both* carbon dioxide and hydrogen sulfide. Compare the potassium carbonate method's cost and economy with other gas-removal systems.

Mail the coupon below!

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Mail to Solvay, without obligation. Check articles desired:

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- ☐ "CO_2 Removal from Natural Gas"—Oil and Gas Journal.
- ☐ "Economics of Acid-Gas Removal"—Oil and Gas Journal.
- ☐ "Improved Process for CO_2 Absorption"—Chemical Engineering Progress.
- ☐ "Hot Potash Process for Gas Purification"—Oil and Gas Journal.
- ☐ "Which CO_2 Removal Scheme Is Best?"—Petroleum Refiner.
- ☐ "New Potassium Carbonate Process"—Petroleum Refiner.
- ☐ "Solvay Potassium Carbonate" fact book.

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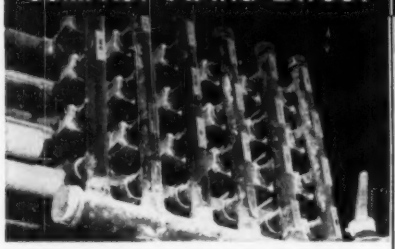
ILLUSTRATED:
1" SIZE
SIZE RANGE:
¼" TO 6"

THE ECON-O-MISER BALL VALVE

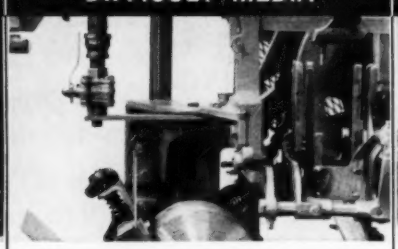
COMPACT PIPING LAYOUT



Here are 19 Econ-O-Miser Ball Valves compactly installed on this paint blending manifold. Note the absence of unions . . . this valve is both a valve and a union! The Econ-O-Miser is smaller, easier to install . . . just right for modern piping layouts, where equipment must fit into tight areas.

Let us show you . . . in your own plant! Write us about your limited space problems!

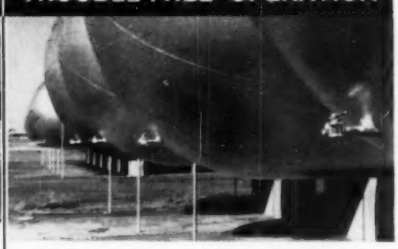
DIFFICULT MEDIA



The Econ-O-Miser Ball Valve successfully controls the flow of cold glue with a viscosity of molasses, on the WORLD Tandem Labeler manufactured by Economic Machinery Co. Clean wiping action, positive leakproof shut-off, and smooth round flow, make the Econ-O-Miser ideal for handling difficult media.

Let us show you . . . in your own plant! Write us about your media problems!

TROUBLE-FREE OPERATION



Outdoor propane and butane storage tanks in remote field processing plants require dependable positive shut-off valves on bleed lines. The unique features of the Econ-O-Miser Ball Valve provided the practical answer . . . no lubrication . . . no metal-to-metal contact . . . quick visual ON-OFF indication . . . trouble-free service.

Let us show you . . . on your outdoor applications! Write us about your valve maintenance problems!

COMPARE . . . THE ECON-O-MISER BALL VALVE

NO UNION NECESSARY

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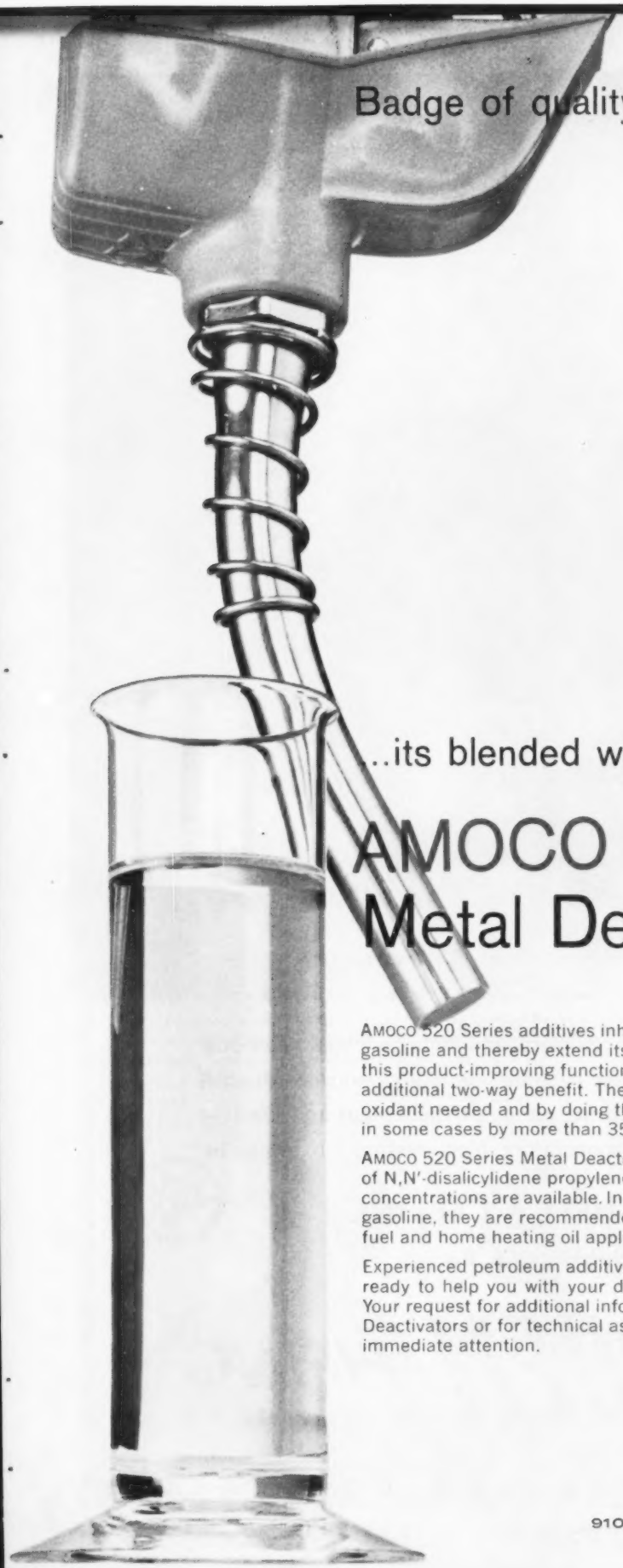
For more data on advertised products, use Readers' Service Cards, last page.

Badge of quality for a gasoline



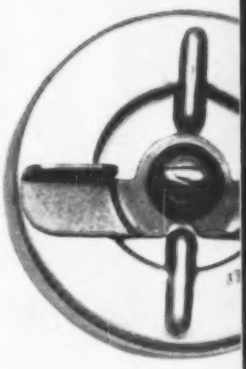
...its blended with

AMOCO 520 Series Metal Deactivators

AMOCO 520 Series additives inhibit copper contamination of gasoline and thereby extend its storage life. While performing this product-improving function, these additives provide an additional two-way benefit. They reduce the amount of anti-oxidant needed and by doing this, they lower treatings costs—in some cases by more than 35%.

AMOCO 520 Series Metal Deactivators are solutions of N,N'-disalicylidene propylenediamine in xylene. Three concentrations are available. In addition to their use in automotive gasoline, they are recommended for kerosene, jet fuel, diesel fuel and home heating oil applications.

Experienced petroleum additive specialists from Amoco are ready to help you with your distillate fuel treating program. Your request for additional information about AMOCO Metal Deactivators or for technical assistance will receive immediate attention.



AMOCO CHEMICALS

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He looks like a man with proper equipment and the experienced know-how to use it. There you have the same combination that commends Mitchell specialists to you for prefabricating piping at their plant and erecting in the field. On your next high-temperature, high-pressure job, ask us in.

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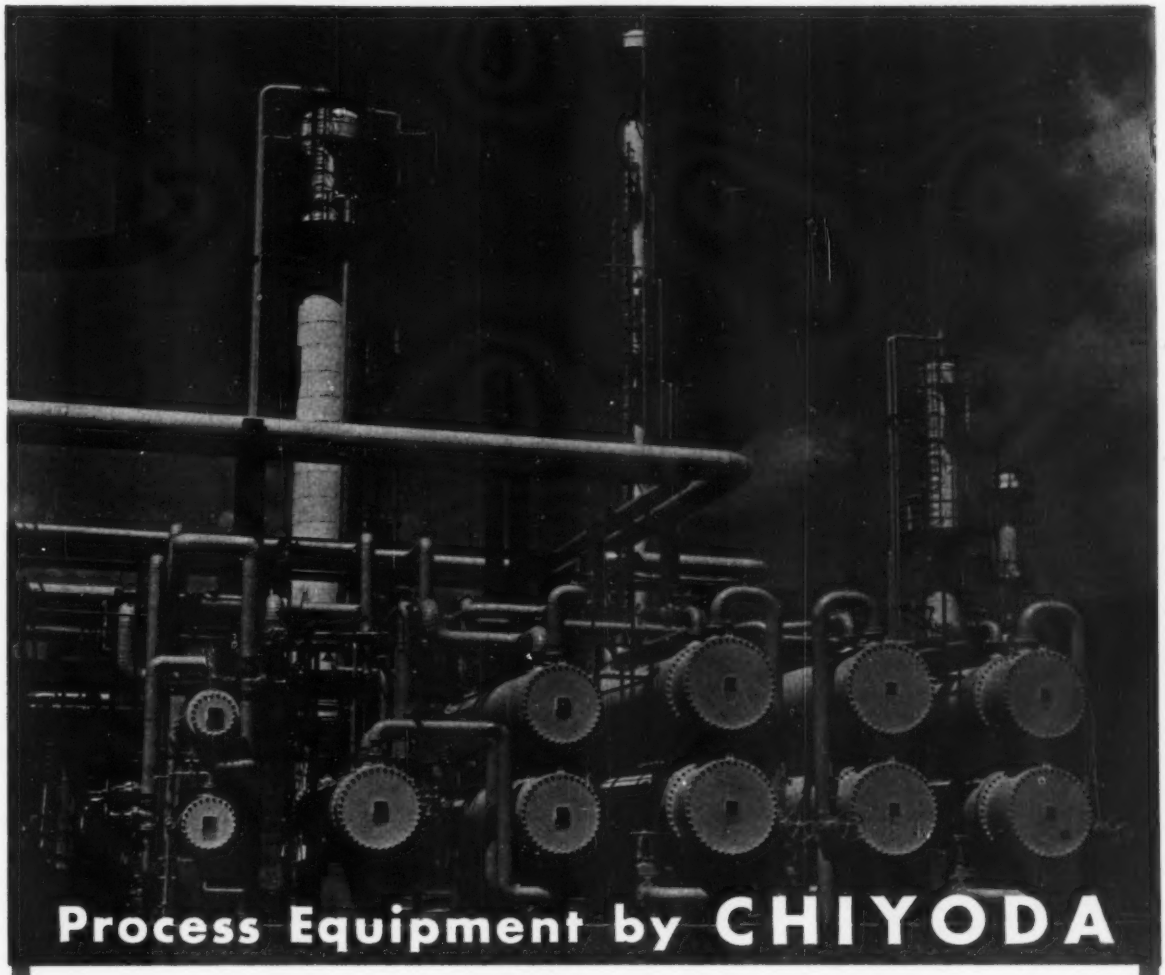
Philadelphia 46, Pa.

WESTPORT JOINT
(PATENTED)

MITCHELL PIPING
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS



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Heat exchangers, towers, vessels, tanks and other process equipment, large or small, single or by the scores, standard or special, are fabricated at Chiyoda's Kawasaki Factory with the most modern fabricating and testing equipment.
With an integrated organization staffed by specialists in every field plus lower man-hour costs, Chiyoda assures clients of early delivery, low maintenance cost, high operating efficiency and long life.
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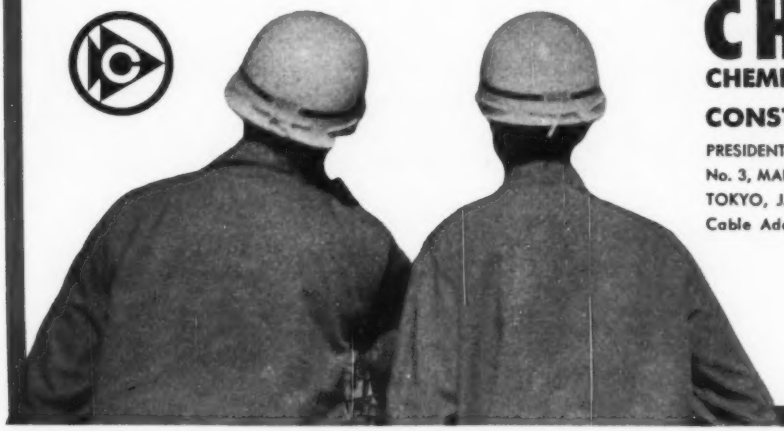
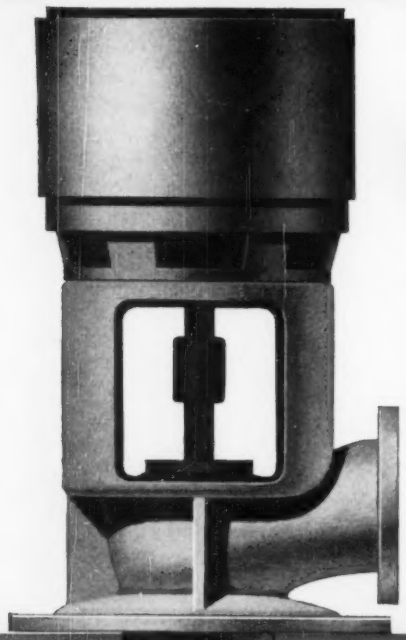
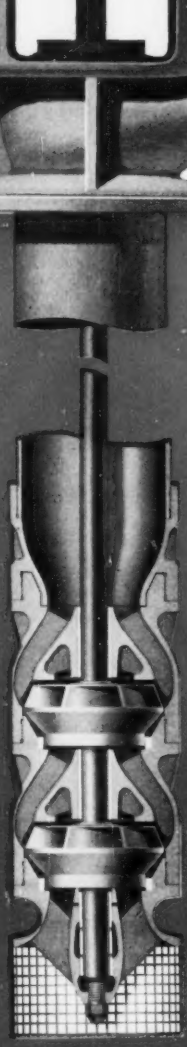


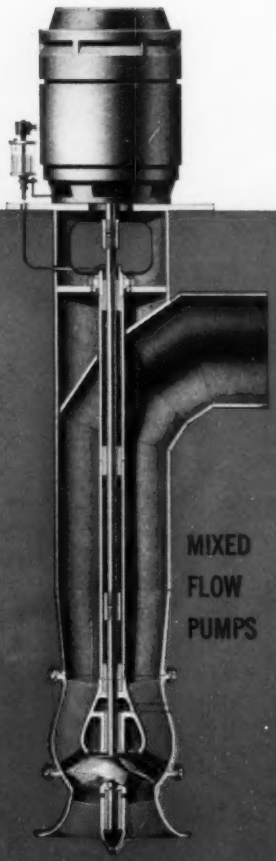
For more data on advertised products, use Readers' Service Cards, last page.



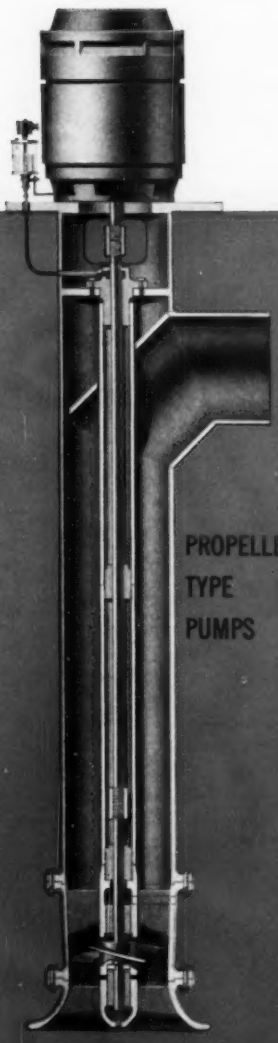
Layne SHORT COUPLED SERVICE PUMPS for any job



TURBINE TYPE PUMPS



MIXED FLOW PUMPS



PROPELLER TYPE PUMPS

Capacities — 50 to 100,000 GPM
Heads — Up to 2,500 Ft.
Settings — As Specified
Discharge - Surface or underground

Top performance, high efficiency and less maintenance are factors which influence the selection of a short coupled pump. Layne Vertical Service Pumps fulfill these requirements and offer the advantages of lower installation and operation costs, low submergence requirements, simple alignment, no priming and less floor space demands. For any short coupled pumping job . . . specify Layne.

Write For Free Bulletins:
LAYNE TURBINE TYPE SERVICE PUMPS—NO. 300
LAYNE PROPELLER AND MIXED FLOW PUMPS—NO. 350

World's Largest Layne Water Developers

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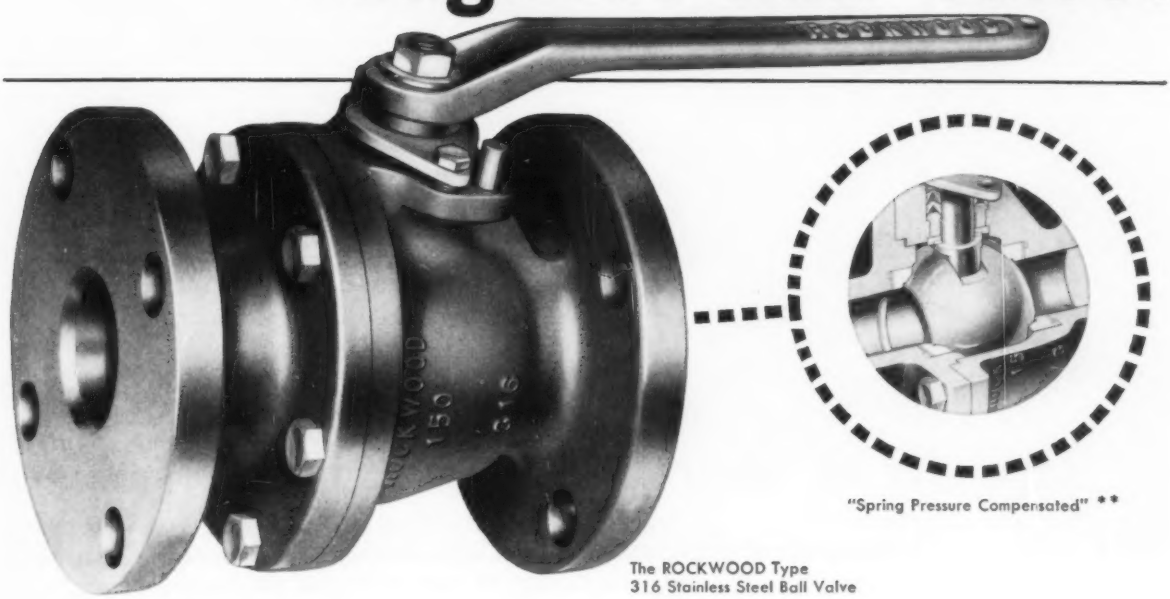
NEW...

Today's "Tightest" and Toughest Ball Valve!



"Spring Pressure Compensated" **

The ROCKWOOD Type
316 Stainless Steel Ball Valve

Here's the new 316 stainless steel ball valve that not only gives you maximum corrosion resistance, but also *positive* assurance of leakproof service!

It's Tightest because exclusive spring rings back up its twin Teflon* seats . . . *automatically* compensate for pressure variations, wear, cold-flow deformation and temperature effects. With flow in either direction . . . under vacuum or 600 psi . . . seats always hug the ball.

It's Toughest because it's made with integrally cast flanges or screw ends. They *stay* leakproof even under constant vibration.

You get all the other ROCKWOOD features, too: smooth, full round flow; easy ¼ turn opening and closing; dead tight sealing without lubrication; and many more. For use at temperatures from −65°F to 350°F, the Type 316 can be easily modified for cryogenics applications. Always tight in vacuum service, too. Handles air, alcohols, fuel and inert gases, water glass and many other fluids. For service up to 600 psi. 4 models available. Sizes ⅜" through 2". Send coupon for complete details. Tested and listed by Underwriters' Laboratories, Inc.

*DuPont Reg. T.M. Teflon seals include seats and adjustable chevron stem packing. Also available with nylon or synthetic rubber seals.

**Patent Pending

ROCKWOOD BALL VALVES

FULL, ROUND FLOW

Distributors in all principal industrial areas

ROCKWOOD SPRINKLER DIVISION
of The Gamewell Company • A Subsidiary of E. W. Bliss Company
225 Harlow Street, Worcester 5, Massachusetts

Please send full details on the new Type 316 Stainless Steel Ball Valve

Name ..... *Title* .....

Company .....

Street .....

City ..... *Zone* ..... *State* .....

For more data on advertised products, use Readers' Service Cards, last page.

STRATCO

Selective Extraction of ISOAMYLENES

for the Production of "Synthetic Natural" Rubber

Stratford Engineering Corporation is pleased to announce its appointment as exclusive licensing agent offering Sinclair Refining Company's new Isoamylene Extraction Process.

High purity Isoamylene is a valuable intermediate in the production of cis-polyisoprene. With the current rapidly developing diene rubber field, this process will enable refiners to realize substantial profits from the C_5 olefins they produce. These olefins are also frequently undesirable in motor gasoline and are costly to remove by other methods.

Inquiries concerning the application of the process are invited.

(See article featured on Page 211 of this issue)

STRATFORD ENGINEERING CORPORATION • PETROLEUM REFINING ENGINEERS

612 West 47th St. Kansas City 12, Mo.

REPRESENTATIVES

D. D. Foster Co., Pittsburgh, Pa.
D. D. Foster Co., S. Charleston, W. Va.
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Rawson-Houlihan Co., Inc., Houston
Rawson-Houlihan Co., Inc., Beaumont, Texas
The Rawson Co., Inc., Baton Rouge
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1960

A SERVICE THAT ADDS YEARS TO COATING LIFE

This tiny instrument — a film thickness gauge — can mean years more protection for your equipment. It helps find those thin spots in coatings that need extra attention to assure the longest and best possible corrosion resistance. This is just one of the tests conducted by Napko Sales Engineers while rendering follow-through service.

With Napko Industrial Coatings, you get superior formulations that provide heavier protective films in fewer coats, designed to fit your special needs, plus *that one crucial ingredient that doesn't come in the can* — the extra protection of dependable follow-through service by a qualified Sales Engineer.

Whatever, wherever, your corrosion problems may be, there's a Napko Industrial Coating to meet your specifications. Just call or write your nearest Napko Industrial Sales Office.

PROJECT SERVICES OF NAPKO CORPORATION

1. Climatic-Operational Analysis
2. Lab Testing & System Research
3. Field Testing
4. Paint Crew Training
5. Job Inspection in Progress
6. Case History for Repaint

Complete Coating Systems for every Industrial Requirement.

NAPKO CORPORATION

INDUSTRIAL COATINGS DIVISION

P. O. BOX 14126 • HOUSTON 21, TEXAS

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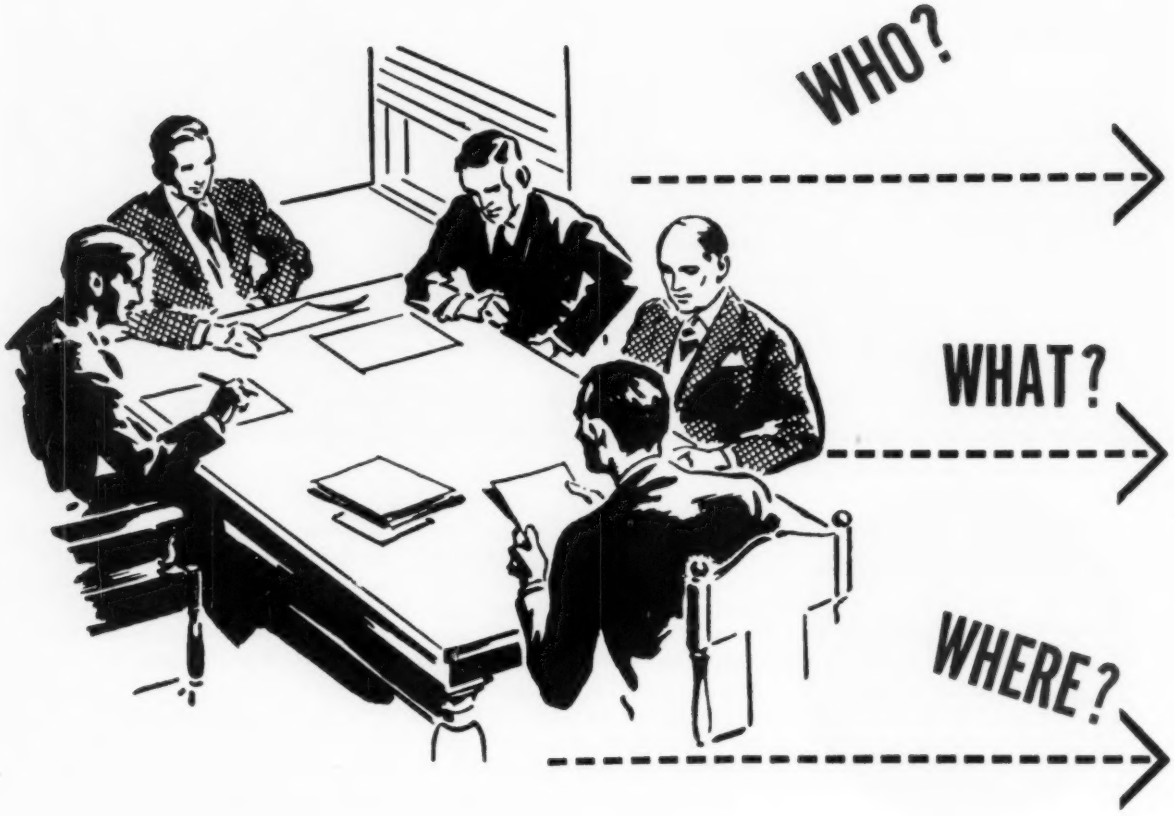
With Men

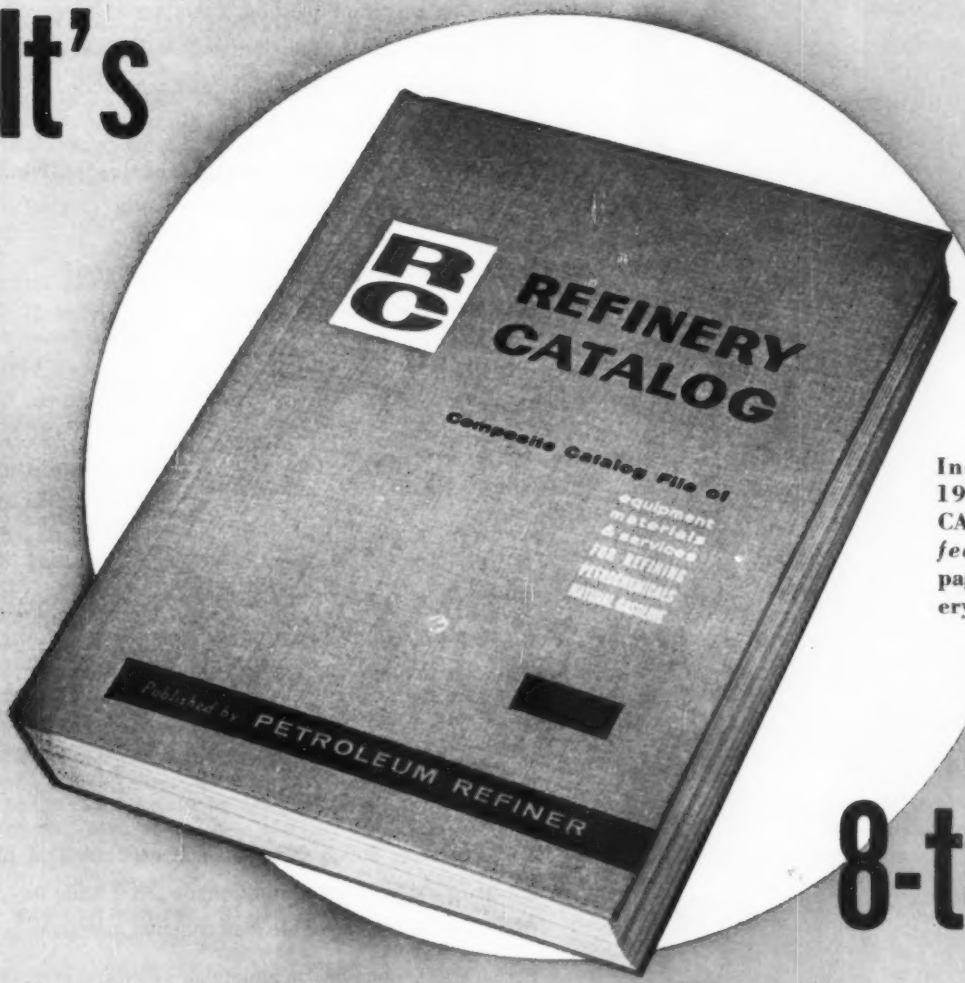


REFINERY CATALOG

Published by Petroleum Refiner

Who Buy And Specify

It's



Included in the 1960 REFINERY CATALOG is a *new feature*—the 128-page A·S·A Refinery Piping Code

8-to-1

Look to REFINERY CATALOG for quick answers to your procurement problems in the refining, natural gasoline and petrochemical industry. It's indexed and cross-referenced to save time and eliminate error in planning, buying and specifying for this fast-moving market. That's why buyers and specifiers express a preference of 8-to-1 for REFINERY CATALOG over individual product catalogs.

The next time *you* sit down to figure a job, look *first* in REFINERY CATALOG. You'll find it contributes to greater speed and accuracy.

"Tell us, Mr. Schwarting..."

How well does J&L Electricweld basic oxygen steel heat exchanger tubing perform day after day on the job?

This is an important question. There are 23 miles of heat exchanger tubing in the giant soda ash plant of Solvay Process Division, Allied Chemical Corporation, in Syracuse, N.Y.

Let one of Solvay's top chemical engineers, Nathan Schwarting, answer the question:

"J&L Electricweld basic oxygen steel tubing gives us superior corrosion resistance...

"Electricweld basic oxygen tubing is easy to install, easy to weld and form...

"The temperature shocks that make some steels separate and pull apart do not seem to affect J&L tubing...

"The uniformly high quality of J&L pressure tubing insures against blisters, or pitting, that form around surface imperfections in tubing...

"It's apparent that all along the line there are J&L workmen who take pains with what they do..."

Experiences of Solvay Process engineers show that J&L Electricweld pressure tubing, made from basic oxygen process steel, has longer life than common materials.

Perhaps J&L open hearth aluminum-killed special soundness quality steel or basic oxygen steel pressure tubing can help you solve heat exchanger or condenser maintenance problems, too. Your J&L sales representative is ready to help—or you can write direct to J&L.

Jones & Laughlin Steel Corporation
ELECTRICWELD TUBE DIVISION
3 Gateway Center · Pittsburgh 30, Pennsylvania

J&L STEEL

Steel

This Steelmark identifies quality products made of steel. Look for it when you buy.

Maintenance and Steam Traps

. . . there's a relationship that goes far beyond trap maintenance alone

Good traps and good trapping have a greater effect on your maintenance costs than does trap maintenance itself. By that we mean that the right traps, properly selected and installed, and with the benefits of a preventive maintenance program, will save far more maintenance dollars than they will cost.

Under the pressure of spiralling maintenance costs, this thought becomes mighty important. Let's take a look at what it involves:

Proper Selection of Steam Traps

1. Be sure it's the right type of trap.
2. Be sure it's sized right and is for the correct operating pressure.
3. Be sure it's first rate in design and construction.

Proper Installation of Steam Traps

1. Install them so they are accessible for inspection and maintenance.
2. Install a test valve.
3. Use a union or unions.
4. Use a shutoff valve or valves.
5. Use a strainer ahead of the trap if dirt conditions are bad.
6. Use a by-pass only where continuity of service is imperative.
7. Standardize inlet and outlet connections.

Preventive Maintenance Program

1. Test trap regularly for proper operation. (Trap size, operating pressure and importance determine frequency.)
2. Inspect internal mechanism at least once a year.

You Get Indirect Benefits As Well

The direct benefits of the plan outlined are pretty obvious — good traps, properly selected, require less maintenance . . . testing and inspection prevents troubles that lead to maintenance.

However, this plan provides indirect benefits which reduce maintenance in other parts of the plant as well:

Good traps save steam and burning equipment and on ash handling equipment.

Good traps protect the system by eliminating water hammer and preventing the damage it can do.

Good traps discharge carbon dioxide before it can go into solution to form corrosive carbonic acid — less corrosion, less maintenance.

Good traps increase production to reduce the length of time equipment must operate or reduce the amount of equipment needed . . . either way maintenance is reduced.

How to Go About It (The Sales Pitch)

We admit we're prejudiced, but we don't think there is any better way to select steam traps than with the help of the 44 page Armstrong Steam Trap Book. Here in a single source is specific data on the selection and sizing of traps, how to install them for best results, and how to maintain them most economically.

The Steam Trap Book will also give you full information on the design and construction of Armstrong Inverted Bucket Steam Traps that offer these important maintenance-reducing advantages:

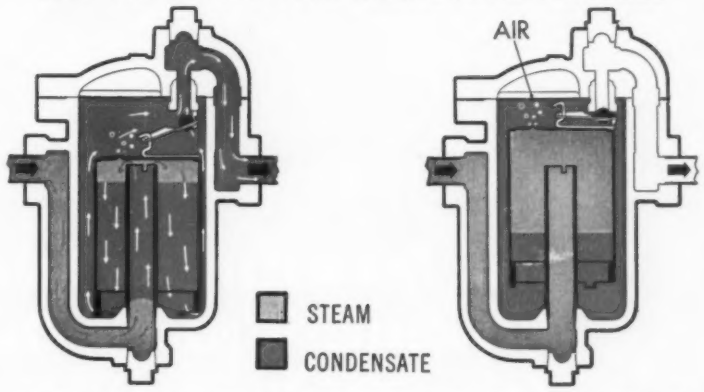
1. Armstrong Traps are dependable.
2. Armstrong Traps require no adjustments — go from full load to zero load automatically.
3. Armstrong Traps are self-scrubbing — ordinary dirt conditions can't hurt them.
4. Armstrong Traps have long-life parts — valve and seat are heat treated chrome steel — lever assembly and bucket are stainless steel.
5. Armstrong Traps have water sealed valves to minimize wire drawing and erosion.

Ask for your copy of the Steam Trap Book—there is no obligation. Then test Armstrong Trapping. If you are not completely satisfied with the results, you can return the traps for a full refund of the purchase price. You can't lose much that way. Call your local Armstrong Representative or Distributor, or write

Armstrong Machine Works
8526 Maple Street
Three Rivers, Michigan

ARMSTRONG STEAM TRAPS

HERE'S THE STEAM TRAP DESIGN THAT CAN REDUCE YOUR MAINTENANCE PROBLEMS



Trap open. Condensate entering trap has caused bucket to lose buoyancy. Weight of bucket times leverage pulls valve open. Air is discharged along with condensate.

Trap closed. Steam has floated inverted bucket; valve is held tightly closed by system pressure. Air entering trap passes through bucket vent and accumulates at top of trap.

For more data on advertised products, use Readers' Service Cards, last page.

From this modern new headquarters and manufacturing plant in Phoenix, Arizona General Electric *Announces...*

A VAST NEW EXPANSION IN COMPUTER FACILITIES

★ New Information Processing Center

■ New Sales Office

● Existing Sales Office

GENERAL ELECTRIC COMPUTER DEPARTMENT ADDING

11 NEW INFORMATION PROCESSING CENTERS AND 10 NEW SALES OFFICES TO THE 16 SALES OFFICES NOW OPEN!

To better serve your computer needs, eleven new Information Processing Centers will be opened within the next year-and-one-half in addition to the two Information Processing Centers now operating in Arizona. Site surveys are proceeding in seven other key cities for additional processing centers. Ten new computer sales offices will be added to sixteen now open (General Electric presently operates offices in 350 key cities throughout the U.S.).

These vast expansions of facilities, manpower and actual operating computer systems are the direct result of customer confidence in the General Electric Company Computer Department and the great expansion of the computer industry as a whole.

General Electric's competence in the computer field is the product of 40 years' experience. General Electric provides computing and information processing systems for business, industry, science, engineering, education and defense.

If you are considering the application of a computer to your firm's operation, contact the existing Computer Department sales office nearest you or write directly to:

General Electric Company • Computer Dept. • 13449 North Black Canyon Highway • Phoenix, Arizona...today!

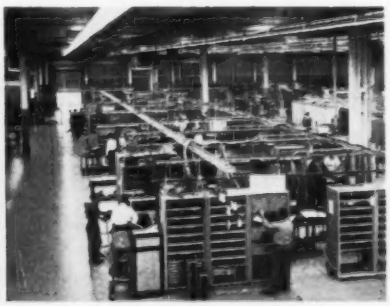
EXISTING SALES OFFICES:
Boston, Massachusetts
Chicago, Illinois
Cleveland, Ohio
Dallas, Texas
Los Angeles, California
Louisville, Kentucky
New York, New York
Philadelphia, Pennsylvania
Phoenix, Arizona
Pittsfield, Massachusetts
San Francisco, California
Schenectady, New York
Seattle, Washington
St. Louis, Missouri
Syracuse, New York
Washington, D.C.

NEW SALES OFFICES:
Atlanta, Georgia
Cincinnati, Ohio
Columbus, Ohio
Denver, Colorado
Detroit, Michigan
Kansas City, Missouri
Minneapolis, Minnesota
New Orleans, Louisiana
Pittsburgh, Pennsylvania
Richmond, Virginia

NEW INFORMATION PROCESSING CENTERS:
Atlanta
Boston
Chicago
Cleveland
Dallas
Minneapolis
New York City
San Francisco Bay Area
Seattle
Philadelphia
Washington, D.C.

General Electric—Pioneer in computer systems for all phases of business, industrial, scientific, engineering and financial endeavor.

Nation's first MICR* Information Processing Center . . . with GE 210 computer system.



General Electric computers on test in modern manufacturing facilities.

GE 312 control computer now operating in various industrial applications.

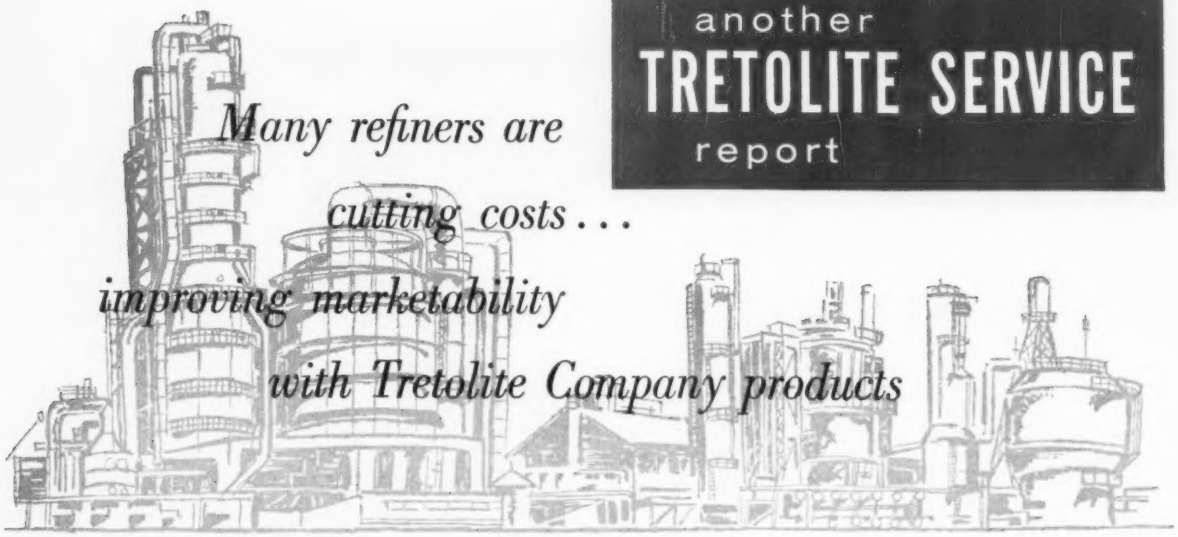
*Magnetic Ink Character Recognition

Progress Is Our Most Important Product

GENERAL ELECTRIC

CPA36 (10-60)

another
TRETOLITE SERVICE
report



Many refiners are cutting costs . . . improving marketability with Tretolite Company products

TRET-O-LITE* *Demulsifiers*

TRET-O-LITE demulsifying chemicals were developed and pioneered to enable producers to reclaim profitably otherwise unmarketable emulsified crudes. Refiners also use TRET-O-LITE emulsion-breakers to salvage usable oil trapped in "tank-bottoms", thereby gaining valuable storage capacity lost when tank-bottoms accumulate. TRET-O-LITE demulsifying chemicals are effectively used to reclaim usable oils from refinery waste disposal systems and separator traps.

If oil and water emulsification is causing an operating problem in your refinery, call Tretolite.

TRET-O-LITE* *Desalting Chemicals*

The Tretolite Company pioneered the use of chemicals in crude oil desalting, and developed the first desalting system in which chemicals provided emulsion destabilizing action.

Refiners all over the world now rely on TRET-O-LITE for efficient, economical desalting performance.

TRET-O-LITE Desalting Chemicals also are widely used in chemical-electric desalting, as well as chemical aid to electric desalting when certain adverse treating conditions are encountered.

Ask your Tretolite Refinery Service Engineer about the economy of TRET-O-LITE *Desalting Chemicals.*

KONTOL* *Corrosion Inhibitors*

KONTOL Corrosion Inhibitors are liquid organic semi-polar compounds available in a variety of formulas. They adsorb at metal surfaces to form an impervious corrosion-inhibiting film. KONTOL Corrosion Inhibitors prevent corrosion in refinery equipment by protecting against attack by chlorides, sulfides, organic acids and hydrogen blistering. They are effective detergents and provide an economical means for maintaining cleanliness and heat transfer efficiency in condensers and exchangers.

KONTOL *Corrosion Inhibitors have been cutting maintenance costs for refiners for many years. Complete information is yours on request.*

TOLAD* *Fuel Additives*

TOLAD Fuel Additives are ashless, totally oil-soluble compounds. They stabilize color in heating oils and diesel fuels. They effectively disperse the insoluble solids which form sludge and impair burning qualities.

TOLAD additives have excellent water tolerance characteristics which prevent loss to water bottoms in fuel storage. They are available as inhibitor or inhibitor-dispersant formulations. TOLAD is approved, and used, by leading railroads.

Get all the facts on this new Tretolite product. In test after test, TOLAD *has provided better fuel stability at lower cost. Why not prove this to your own satisfaction—and profit.*

For complete information on these, or any Tretolite Company product or service, ask the Man in the Red Car, or write

AR-60-3

*Registered trademark of Petrolite Corporation

PETROLITE
CORPORATION

TRETOLITE COMPANY
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5515 Telegraph Road, Los Angeles 22, California

CANADA: Petrolite Corporation of Canada, Limited, Edmonton, Alberta
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ENGLAND: Petrolite Limited, 20 Savile Row, London W.1
GERMANY: Petrolite Anlagenbau und Vertriebsgesellschaft m.b.H., Frankfurt a. M.
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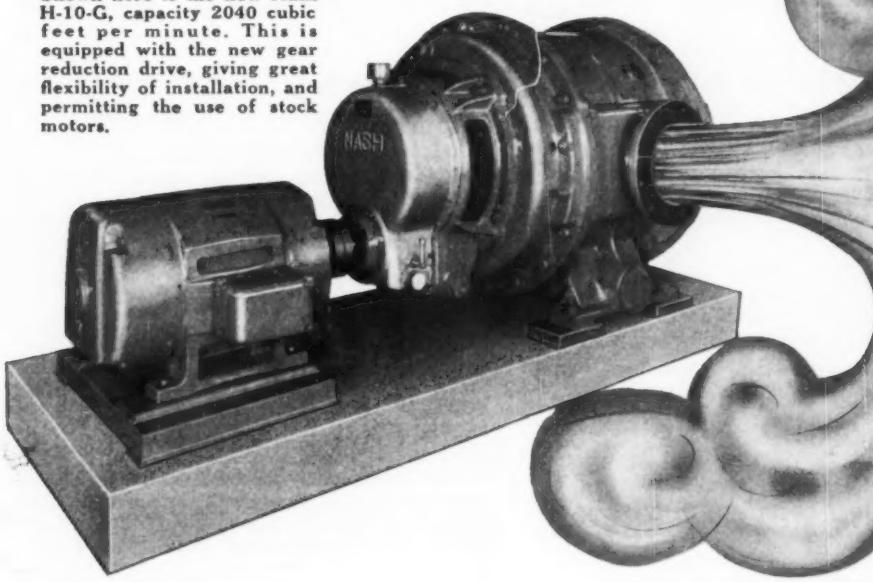
MEXICO: R. E. Power, Sierra de Mijes No. 125, Mexico, D. F.
NETHERLANDS: F. E. C. Jenkins, Hoefbladlaan 134, The Hague
PERU: Oilfield Import, S. A., Apartado 71, Talara
TRINIDAD: Neal and Massy, Ltd., P. O. Box 544, Port of Spain

Nash Compressors Tame "Hard-to-handle" Corrosive Gases

The reasons for the success of Nash Compressors in handling "dirty" and corrosive gases are simple. First, Nash Compressors have no internal parts in wearing contact, or requiring close tolerances and internal lubrication. Second, because of the Nash operating principle, a variety of liquids can be employed as the compressant medium, protecting the interior from corrosive action. Third, the pump casing may be fabricated from a variety of special metals and alloys. That is why Nash Compressors take these rugged jobs in stride.

Nash Vacuum Pumps offer the same basic advantages when handling corrosive gases, and reliably maintain vacuums up to 29.50 inches of mercury.

Shown here is the new Nash H-10-G, capacity 2040 cubic feet per minute. This is equipped with the new gear reduction drive, giving great flexibility of installation, and permitting the use of stock motors.

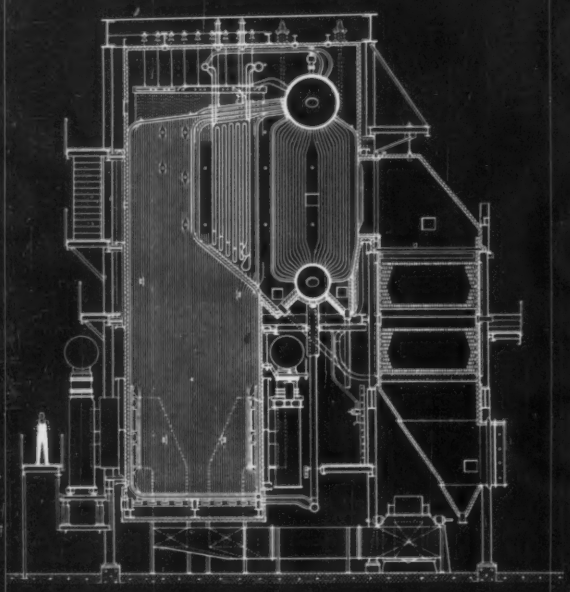


ACETONE
ACETYLENE
AMMONIA
ARGON
BUTADIENE
CARBON DIOXIDE
CARBON MONOXIDE
CHLORINE
ETHYL CHLORIDE
FLUE GAS
FURFURAL
HEXANE
HELIUM
HYDROGEN
HYDROGEN SULPHIDE
NITROGEN
OXYGEN
PHOSPHOROUS PENTOXIDE
SULPHUR GAS
VINYL ACETATE
VINYL CHLORIDE
AND MANY OTHERS

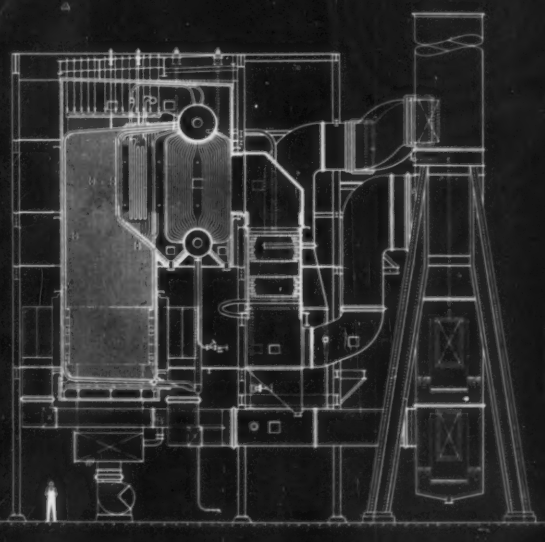
NASH ENGINEERING COMPANY

SOUTH NORWALK, CONNECTICUT, U. S. A.

This unit delivers 175,000 lb of 750F steam per hour at 650 psig. In addition to CO gas, it burns pitch, refinery gas and Bunker C oil.



One of two CO boilers for a Texas refinery. Oxygen for combustion is supplied by the exhaust from the gas turbines which drive the regenerator compressors. Steam conditions are 177,000 lb per hr, 625 psig and 700F.



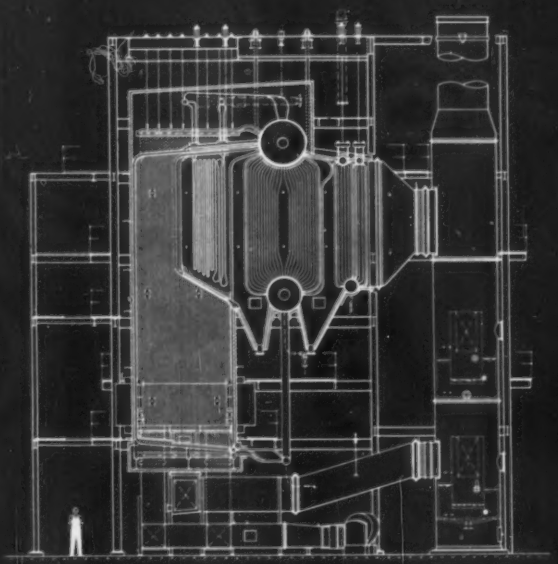
If you're looking for the best catalyst regenerator gas

Here are 8 reasons why

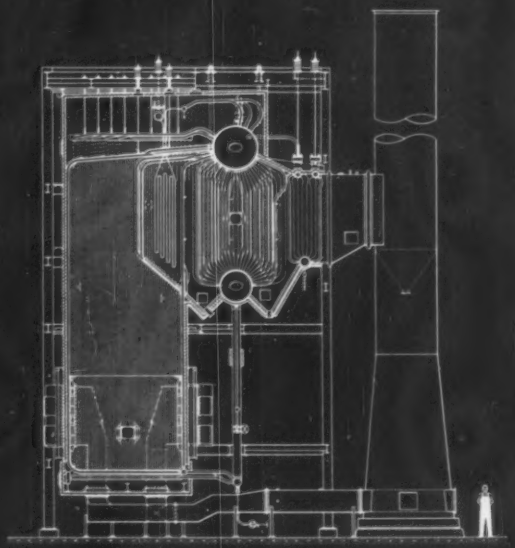
1. **YOU'LL WANT HIGH AVAILABILITY**
   And the records show that the first CO Boiler placed in service by C-E has been on the line for more than two years without a single unscheduled boiler outage.
2. **YOU'LL WANT OPTIMUM RETURN**
   And CO Boilers by C-E burn regenerator gas efficiently *from minimum to maximum loads.*
3. **YOU'LL WANT LOW POWER CONSUMPTION**
   And CO Boilers by C-E provide minimum air pressure loss and minimum fan horsepower requirements.
4. **YOU'LL WANT LOW MAINTENANCE**
   And double steel, skin cased CO Boilers by C-E contain a minimum of exposed refractory.
5. **YOU'LL WANT THE MOST EFFECTIVE USE OF MATERIALS**
   And C-E makes optimum use of boiler and superheater – gas passage areas and heating surfaces are uniformly distributed across the width of the unit.
6. **YOU'LL WANT ADVANCED DESIGN**
   And C-E Tangential Burners provide complete and positive mixing of air, auxiliary fuel and CO gas, preparing the combination for instantaneous ignition on injection in the furnace.
7. **YOU'LL WANT MAXIMUM CONTROL OF THE COMBUSTION PROCESS**
   And CO Boilers by C-E offer individual, shielded cut-off dampers for each CO gas burner and individual air control for every burner.
8. **YOU'LL WANT A PRODUCT THAT HAS PROVEN ITSELF**
   In terms of general experience, a total of more than 675 tangentially fired C-E boilers have been purchased to date for use with various fuels. As to specific experience with lean fuels, C-E – in addition to its CO Boiler installations in refineries – has installed more than 150 boilers burning blast furnace gas . . . a fuel similar to CO gas with a heating value of about 80 Btu per cubic foot.

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;

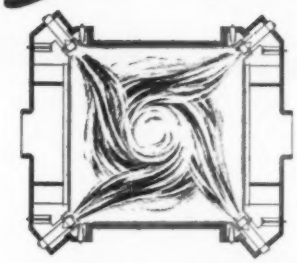
This unit is designed to produce 85,000 lb of 750F steam per hour at 625 psig. Note the C-E seal tank arrangement in the bottom-supported stack.



In its third year of service, this unit provides 100,000 lb of 550F steam per hour at a pressure of 250 psig. It has been off the line only when the cat cracker was removed from service for scheduled maintenance.

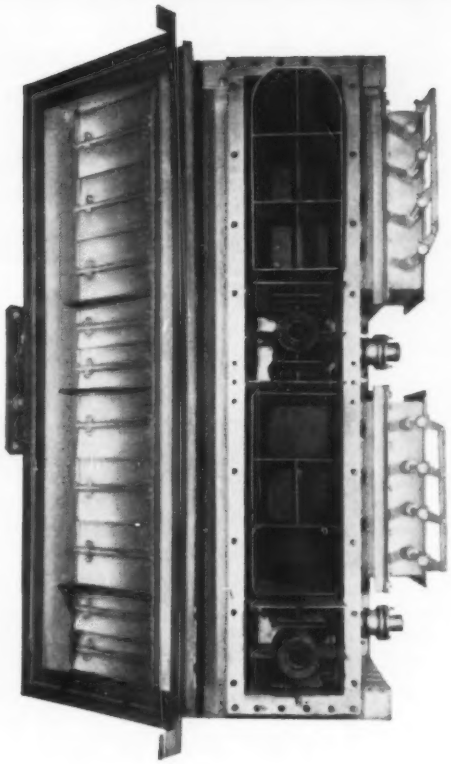


boiler to burn
See C-E



Plan view diagram showing principle of tangential firing in a completely water-cooled furnace.

The C-E Tangential Burner for CO gas. Zone controlled, dampered air inlets are shown at left, dampered CO gas inlets at right. The center panel is a furnace view of the burner The oil burners in the cen ter and bottom compartments are flanked by flat head burners for natural or refinery gas firing. CO gas is admitted through the other ports.



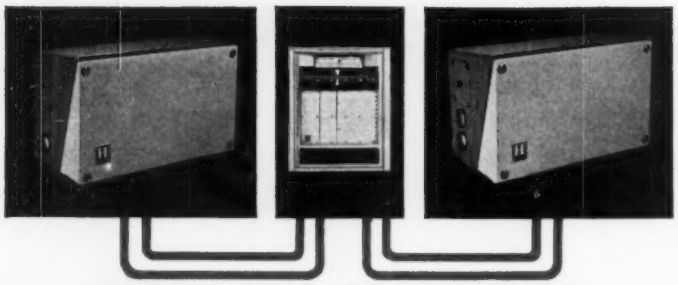
COMBUSTION ENGINEERING

C-E

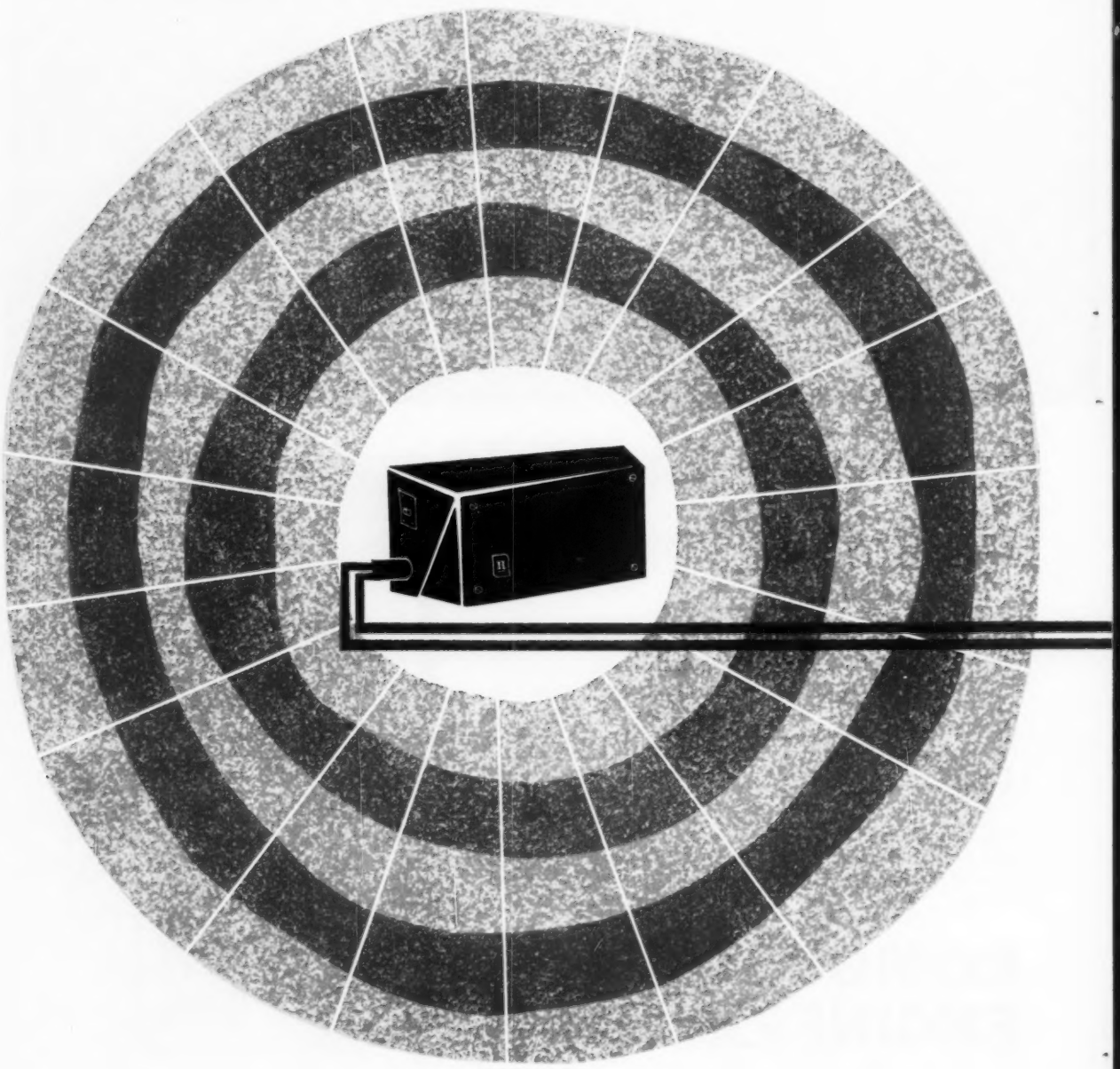
C-148

General Offices: Windsor, Connecticut
New York Offices: 200 Madison Avenue, New York 16, N. Y.

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE



***ElectriK Tel-O-Set*—the true 2-wire system**



TAKING THE HEAT OFF FIELD-MOUNTED TRANSMITTERS

The *ElectriK Tel-O-Set* System takes the heat off field-mounted instruments by *eliminating heat-generating tubes and power packs.* There's no external power required at any *Tel-O-Set* field-mounted instrument. The line power connection is made only at the receiver.

Tel-O-Set field-mounted instruments operate on a low calorie diet of 4-20 milliamps . . . less than 0.6 watts. A simple two-wire line connects the field-mounted instruments with the control room. The two wires carry the control signal as well as the power. The d-c transmission avoids stray pickup and phasing problems . . . eliminates the need for shielding the line.

The 4-20 milliamp signal range of the system gives a live zero and permits the use of the most reliable transistors available. These d-c signals can be fed into data handling systems and millivolt-actuated instruments . . . can be easily transduced to a standard 3-15 psi pneumatic signal to operate existing pneumatic systems.

The basic circuit used in *Tel-O-Set* transmitters, receivers, controllers and other instruments has been thoroughly proved in thousands of applications in the last five years. This circuit uses a force-balance feedback system to increase the accuracy and the dynamic response of the system by decreasing hysteresis effects and sensitivity to changes in ambient conditions.

Take a new look at your control applications with the *ElectriK Tel-O-Set* System in mind! Get complete technical data from your local Honeywell field engineer. Call him today . . . he's as near as your phone. MINNEAPOLIS-HONEYWELL, 21 Penn Street, Fall River, Mass.

Honeywell

First in Control

SINCE 1885

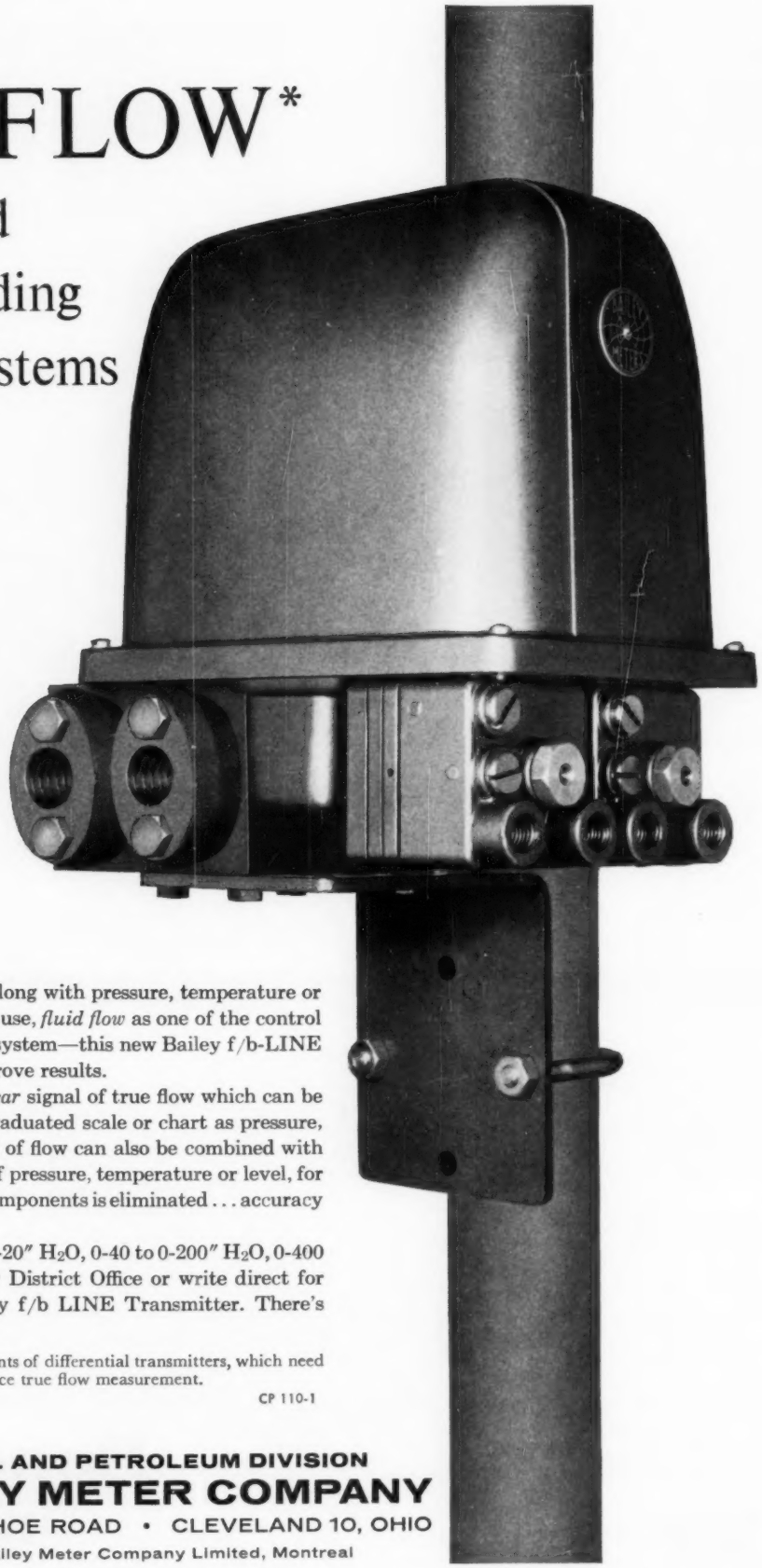
75th YEAR — PIONEERING THE FUTURE

For more data on advertised products, use Readers' Service Cards, last page.

Measures

TRUE FLOW*

to simplify and improve recording and control systems



If you intend to record *fluid flow* along with pressure, temperature or level—or if you now use, or plan to use, *fluid flow* as one of the control factors in a multi-element control system—this new Bailey f/b-LINE Transmitter can simplify and improve results.

It measures and transmits a *linear* signal of true flow which can be recorded on the same uniformly graduated scale or chart as pressure, temperature and level. This signal of flow can also be combined with other linear signals such as those of pressure, temperature or level, for improved control. Need for extra components is eliminated . . . accuracy of flow reading is increased.

Wide selection of ranges: 0-4 to 0-20″ H_2O, 0-40 to 0-200″ H_2O, 0-400 to 0-2000″ H_2O. Call your Bailey District Office or write direct for complete data on the new Bailey f/b LINE Transmitter. There's nothing like it.

*As opposed to pressure-drop measurements of differential transmitters, which need external square root extractors to produce true flow measurement.

CP 110-1

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CHEMICAL AND PETROLEUM DIVISION

BAILEY METER COMPANY

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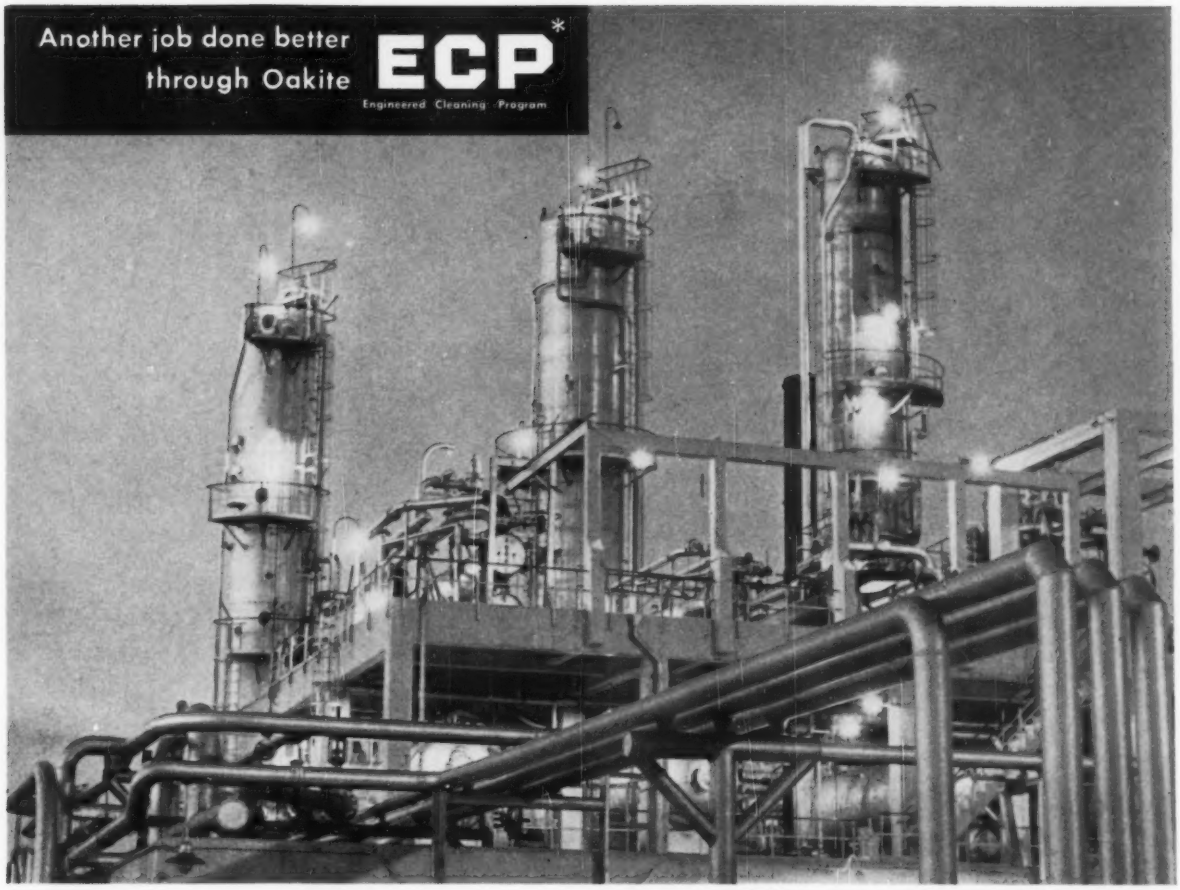
Another job done better through Oakite **ECP*** Engineered Cleaning Program



Refinery saves morale and $6,000 in tough tower turnaround

A refinery recently reported that it was experiencing a near morale breakdown in one of its tower turnaround operations. Twice each year a squad of 20 disgruntled "volunteers," made its way methodically through the tower, shoveling out crude deposits 8 inches thick. A detail of boilermakers followed, dismantling the interior for off-site chipping and tank cleaning. Some men suffered irritations from caustic residue of original process. It was back-breaking work, time consuming—and expensive, too...totaling $13,000 for this one tower. But saving money at this point apparently was not the main concern. The refinery wanted to save *morale.*

The Oakite man recommended in-place circulation of a solution of Oakite 79...a highly effective remover of asphalt and carbon soil combinations. The solution was cascaded over trays and bubble caps and through downcomers. Results: about 80% perfect *after just ten hours* of circulation. Because of a clogged downcomer, half of one tray had to be removed for hand cleaning. *Savings in morale: immeasurable. Overall saving in dollars: $6,000.*

And so, in seeking the answer to a major morale problem through an Oakite Engineered Cleaning Program, this refinery not only solved that problem but also learned first hand that Oakite ECP means dollar savings, too.

*OAKITE ECP's are Engineered Cleaning Programs that stress *chemical cleaning.* They are engineered for specific cleaning operations in your refinery. The Oakite cleaning engineer lends personal and experienced supervision to each phase of a program. He supplies detailed instructions based on practical knowledge of refinery cleaning needs. Each Oakite ECP is backed by *chemical cleaning research,* by materials known to make short work of removing refinery soils and by proven methods. Send for FREE booklets that will help you in your refinery cleaning chores. Oakite Products, Inc., 50B Rector Street, New York 6, N. Y.

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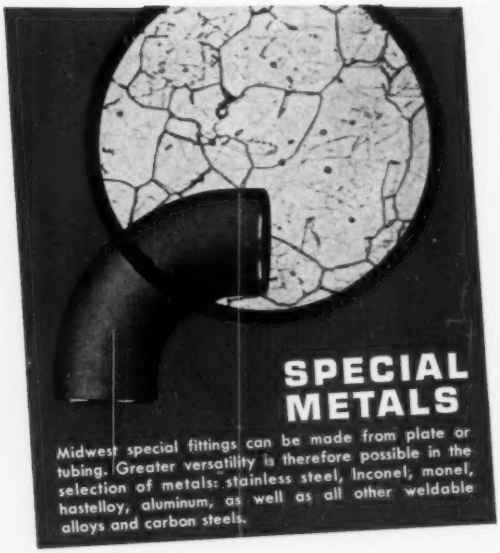
Oakite **ECP** *your economy key*

For more data on advertised products, use Readers' Service Cards, last page.



SPECIAL METALS

Midwest special fittings can be made from plate or tubing. Greater versatility is therefore possible in the selection of metals: stainless steel, Inconel, monel, hastelloy, aluminum, as well as all other weldable alloys and carbon steels.

MIDWEST SPECIAL FITTINGS MADE BY FITTING SPECIALISTS TO YOUR SPECIAL REQUIREMENTS

SPECIAL SHAPES

Midwest's wide experience and skills with forging presses and dies permit forming plate or tubing into unusual shapes for special applications . . . elbows with or without long tangents, wyes, extrusions, and other special configurations.

For special fittings with any or all of the above characteristics, contact your local Midwest distributor . . . or call:

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SPECIAL THICKNESS

Wall thicknesses in a wide range of sizes are available in Midwest special fittings, up to 4" or more in carbon steel and a wide variety of alloys . . . stainless steel, Inconel, titanium, and others.

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the American Institute of Chemical Engineers announces...

A.I.Ch.E. PETROCHEMICAL AND REFINING EXPOSITION!

For some time, the A.I.Ch.E. has been aware of an increasing demand for a petrochemical and refining exposition...to bring together in one place the seemingly inexhaustible number of new developments and new ideas associated with this dynamic and expansive field...and to put it into its proper focus in the overall chemical and petroleum picture.

NOW— for the first time in history—this show becomes a reality!

THE TIME: FEBRUARY 26—MARCH 1, 1961

THE PLACE: NEW ORLEANS, LOUISIANA

will you be there? This is *one* exposition you should not miss, for it will bring together under one roof some of the most important developments in the field...developments that you, as a chemical or petroleum engineer, should know about in intimate detail.

Sponsored by the American Institute of Chemical Engineers, the first Petrochemical and Refining Exposition will be held in conjunction with a national meeting of the A.I.Ch.E. Exhibits will be at the Municipal Auditorium, and meetings will be held there as well as at the Roosevelt Hotel. Fabled New Orleans is the ideal site for this important show—for 85% of the petrochemical industry and 35% of the refining industry are within a radius of a few hundred miles.

Several hundred exhibitors will display their products and services, with equal space being planned for both petrochemicals and refining. Papers presented at the meeting will be among the most important of the year, and will be released simultaneously to all publications. And for a big "plus," many interesting plant trips in the vicinity are being planned for you to attend.

The tentative program will feature sessions on kinetics, petrochemicals, future of the industry on the Gulf Coast, solids, future processing technology in the petroleum industry, liquid-liquid extraction, education and professionalism and many other important subjects.

PLAN YOUR TRIP TODAY!

Hotel space is certain to be at a premium for this unusual show, so we suggest an early reservation. Contact the American Institute of Chemical Engineers, 25 West 45th Street, New York 36, N. Y. for details and further information.

For complete and up-to-date information on the latest petrochemical developments, you should become a member of the American Institute of Chemical Engineers. Just send in this coupon for full information.

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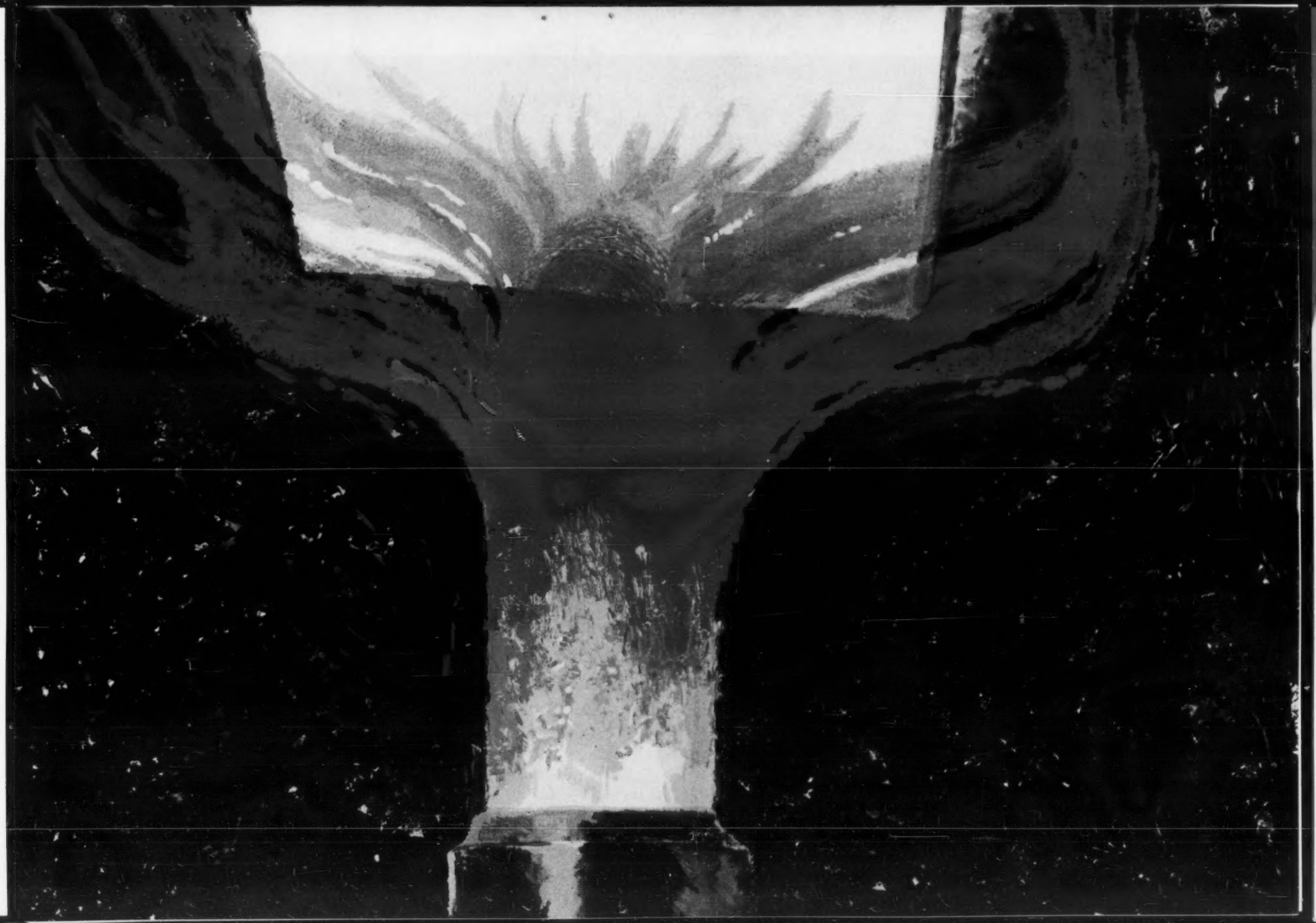

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Here's a material of construction that copes with high temperature, impact, and corrosion.

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For example, if corrosion at high temperatures is a problem, Pfaudler® Nucerite could be the answer, since it resists corrosive vapors at temperatures that would destroy most metals in minutes.

If high-temperature stability is what you're looking for, consider that Nucerite can protect a base metal from oxidation at 2000° F.

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WHAT IT IS. Nucerite is properly classified as a family of ceramic-metal composites in which a ceramic formulation is physically and chemically bonded to a structural base metal.

NOT A GLASSED STEEL. After the ceramic component is applied and fired on, controlled nucleation and crystallization take place during heat-treatment as a result of agents which act as centers of nucleation.

This leads to a ceramic structure with a large number of very small crystals and results in a tough ceramic-metal composite with a unique combination of properties.

Today, Nucerite is a laboratory achievement.

You are invited to make inquiries on possible applications for it and investigate field testing programs. The above lab test data are detailed in Bulletin 999. Use the coupon, or direct your questions to our Pfaudler Division, Dept. PR-110, Rochester 3, New York.

FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids. *Patent applied for

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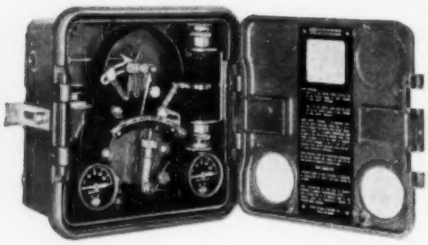

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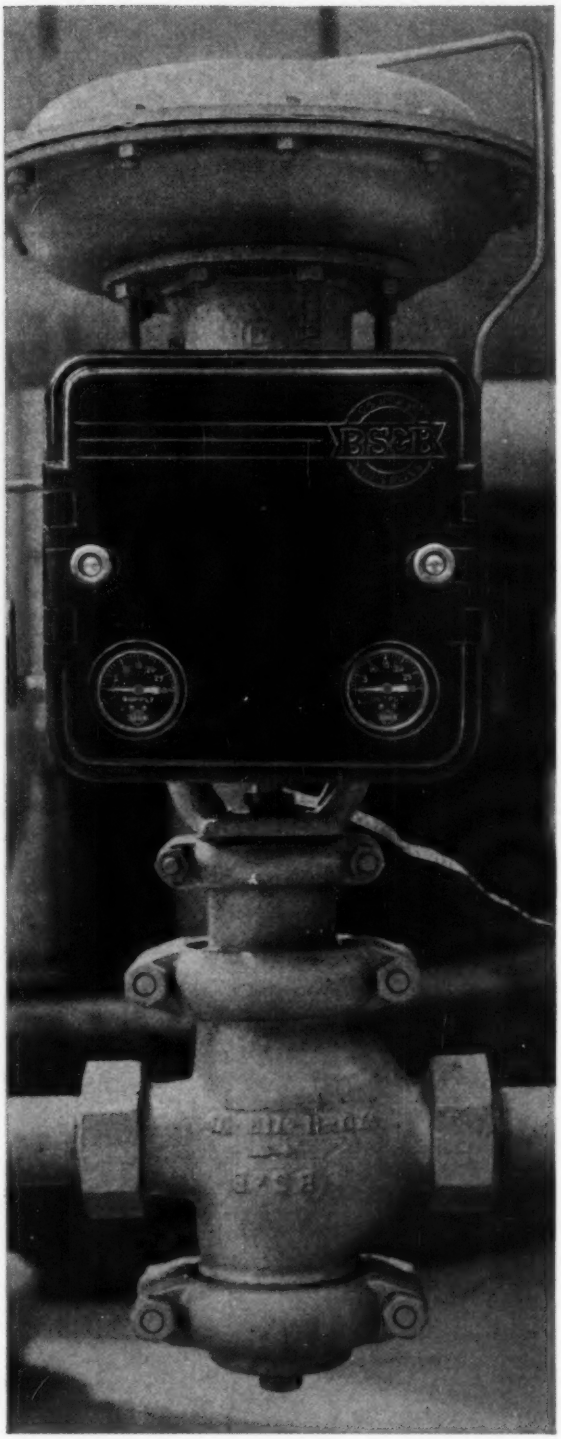
What does this mean to you? With common parts, inventory can be reduced. Delays and shut-downs are held at a minimum. Moreover, the design simplicity which makes the BS&B Pneumatic Controller "Universal" provides years of trouble free operation.

Let our sales engineer show you the many advantages of using BS&B Controlled Systems or write: BLACK, SIVALLS & BRYSON, INC., Dept. 4-F11, 301 N. Cincinnati, Tulsa, Oklahoma.



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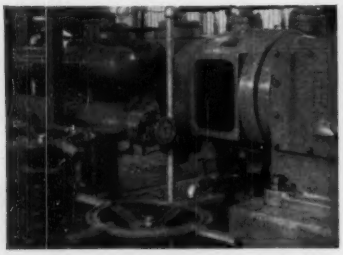
Coppus Turbines are built to customers' specifications, including API and NEMA standards. Sizes from 1 HP to 250 HP. All Coppus Products carry the same Blue Ribbon assurance of reliable performance. For further facts on turbines, send for new Catalog 200. COPPUS ENGINEERING CORPORATION, 421 Park Ave., Worcester, Mass. Sales Offices in *Thomas' Register*.

COPPUS
STEAM TURBINES

Pointer oscillation just 1 of reasons for dampening industrial thermometers

It is generally assumed that industrial thermometers are silicone dampened solely to prevent pointer oscillation when used on vibrating equipment. True, the prevention of pointer oscillation is necessary, but actually there are several far more important reasons for the use of dampening fluids.

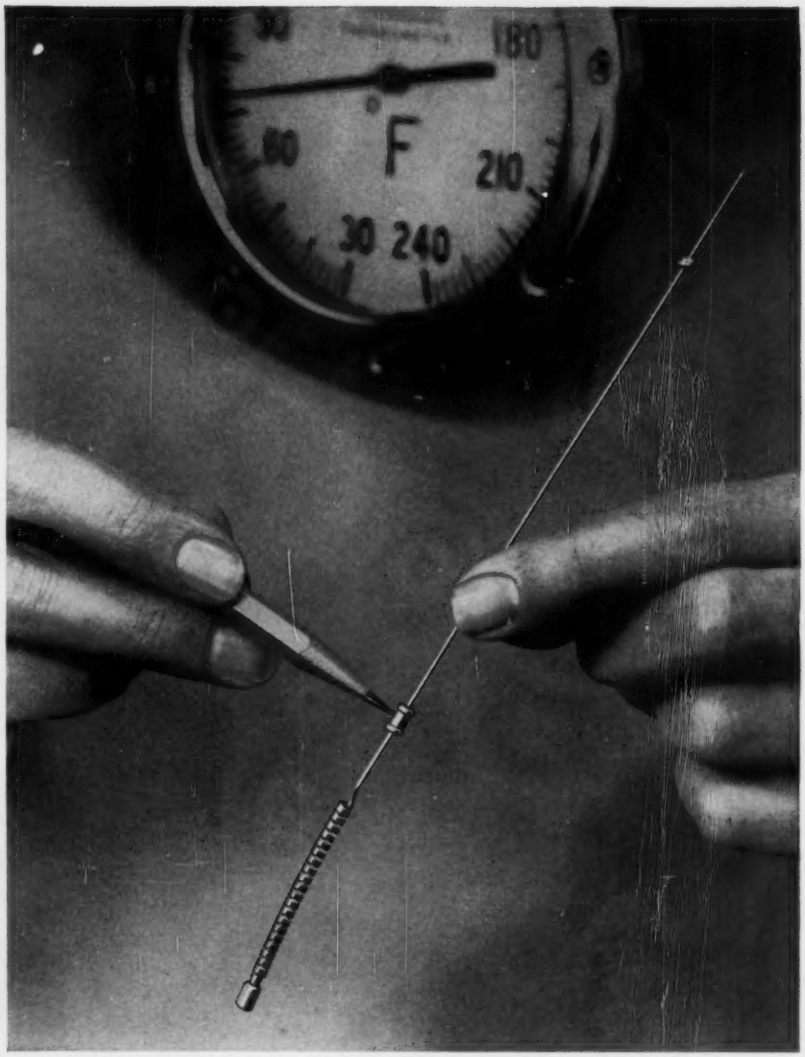
The primary reason for dampening bimetallic dial thermometers is to preserve accurate calibration, especially on the lower temperature ranges where a thinner bimetal element is used. An *un*dampened bimetal element, when subjected to shock or severe vibration, would have a tendency to unwind slightly, throwing the instrument out of calibration. To prevent this, RMC thermometers are dampened by a patented process in which the bimetal element is coated with silicone. The silicone provides permanent protection for the critical bimetal element, holding the coil in place and preventing any unwinding or shifting action. This dampening, of course, also prevents pointer oscillation, eliminating difficult readings. But the main reason for silicone dampening is to help maintain calibration accuracy, and it is therefore quite important to *all* industrial thermometer users.



The RMC thermometer in this photograph is constantly subjected to extreme vibration. It is installed on a two-stage Synthesis Gas Compressor in Atlantic Refinery's Philadelphia Synthetic Ammonia Plant. Only a completely dampened thermometer could maintain its accuracy under such conditions.

There is more, however, to the full dampening story at Rochester Manufacturing Company. RMC carries the procedure one step further with a specially designed bearing which further dampens both the shaft and coil. It also serves as a better guide for the bimetal shaft to keep it perfectly aligned within the tube. RMC is the only manufacturer using this type of dampening bearing at the present time.

Write, wire or phone—tell us your requirements for indicating instruments, and let RMC engineering skill go to work for you. ROCHESTER MFG. CO., 38 Rockwood St., Rochester 10, N. Y.



This special dampening bearing goes one step beyond silicone in the dampening of RMC thermometers. Only RMC uses this *extra* dampening device in addition to silicone and the usual stamped guide bearings. It is a precision machined part, serving several needed dampening functions.

Special bearing *plus* silicone double-dampens RMC thermometers

In RMC bimetal thermometers a specially designed dampening bearing is used just above the bimetal element. This bearing further dampens the shaft, helps to prevent coil unwinding and pointer oscillation, and also serves as a better guide for perfect shaft alignment within the tube. It's the combined use of this dampening bearing *and* silicone that makes RMC thermometers extra resistant to shock and vibration. You get this *only* in RMC industrial thermometers.

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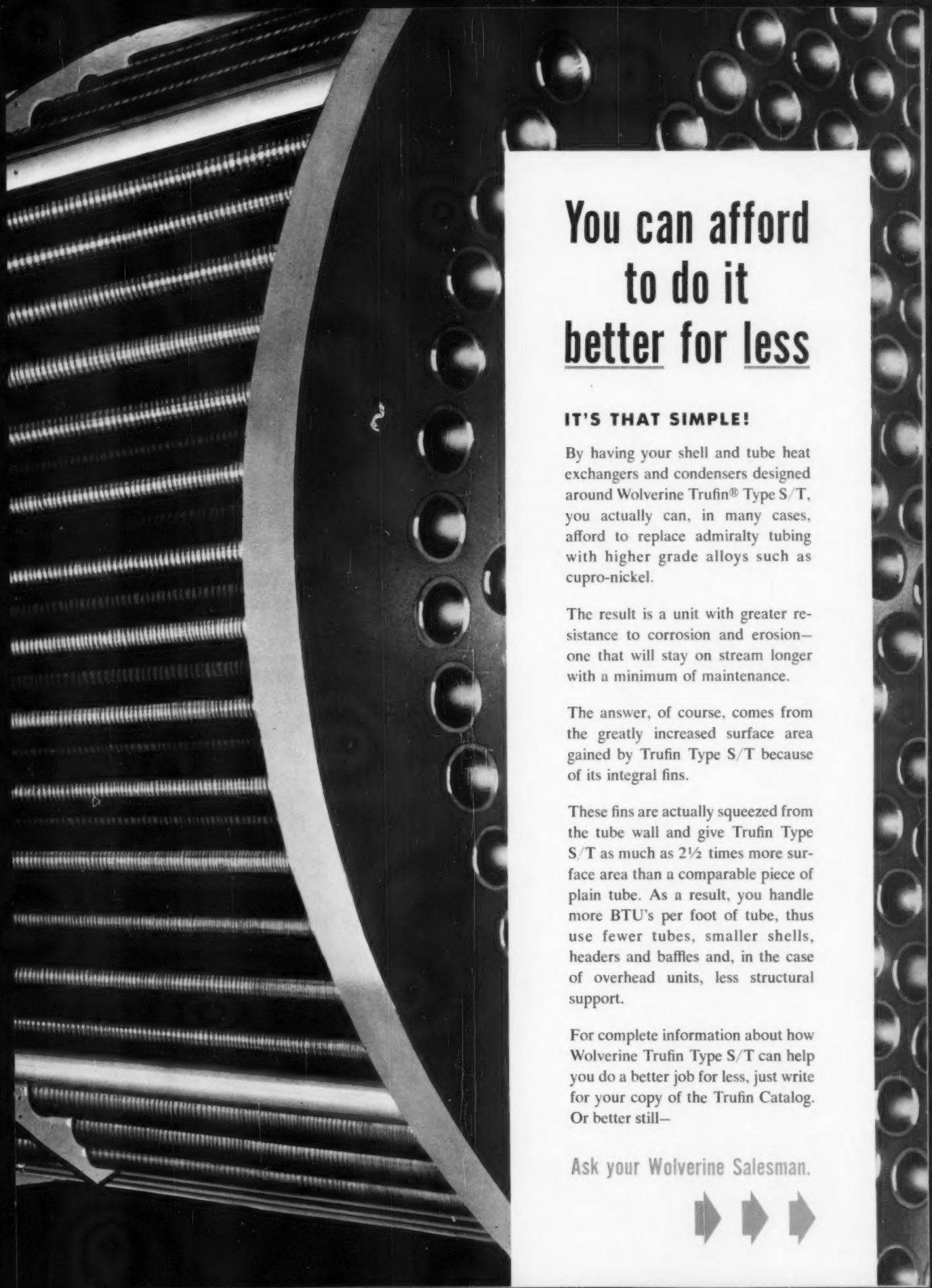

You can afford to do it better for less

IT'S THAT SIMPLE!

By having your shell and tube heat exchangers and condensers designed around Wolverine Trufin® Type S/T, you actually can, in many cases, afford to replace admiralty tubing with higher grade alloys such as cupro-nickel.

The result is a unit with greater resistance to corrosion and erosion—one that will stay on stream longer with a minimum of maintenance.

The answer, of course, comes from the greatly increased surface area gained by Trufin Type S/T because of its integral fins.

These fins are actually squeezed from the tube wall and give Trufin Type S/T as much as 2½ times more surface area than a comparable piece of plain tube. As a result, you handle more BTU's per foot of tube, thus use fewer tubes, smaller shells, headers and baffles and, in the case of overhead units, less structural support.

For complete information about how Wolverine Trufin Type S/T can help you do a better job for less, just write for your copy of the Trufin Catalog. Or better still—

Ask your Wolverine Salesman.

Only Wolverine Tube can offer all these extra condenser tube values

ONLY WOLVERINE?

Yes, that's right . . . because only Wolverine Tube, in the entire tubing industry, has had years and years of experience in manufacturing integrally finned condenser tube.

Wolverine's experience, for example, goes back to 1928 when it first developed Wolverine Trufin. Since then, through its own engineering research, and in conjunction with the University of Michigan, Wolverine Tube has compiled almost all the existing technical data concerning the applications and advantages of integrally finned tube.

This too, is why only Wolverine Tube is able to offer tubing users the services of its staff of Heat Transfer Specialists–highly trained men who know exactly how integrally finned tubing can help you.

Yes, only Wolverine–because of its research and years of experience–can give you truly competent finned tube guidance. For the complete story write for your copy of the Trufin Catalog.

HEAT TRANSFER SPECIALISTS

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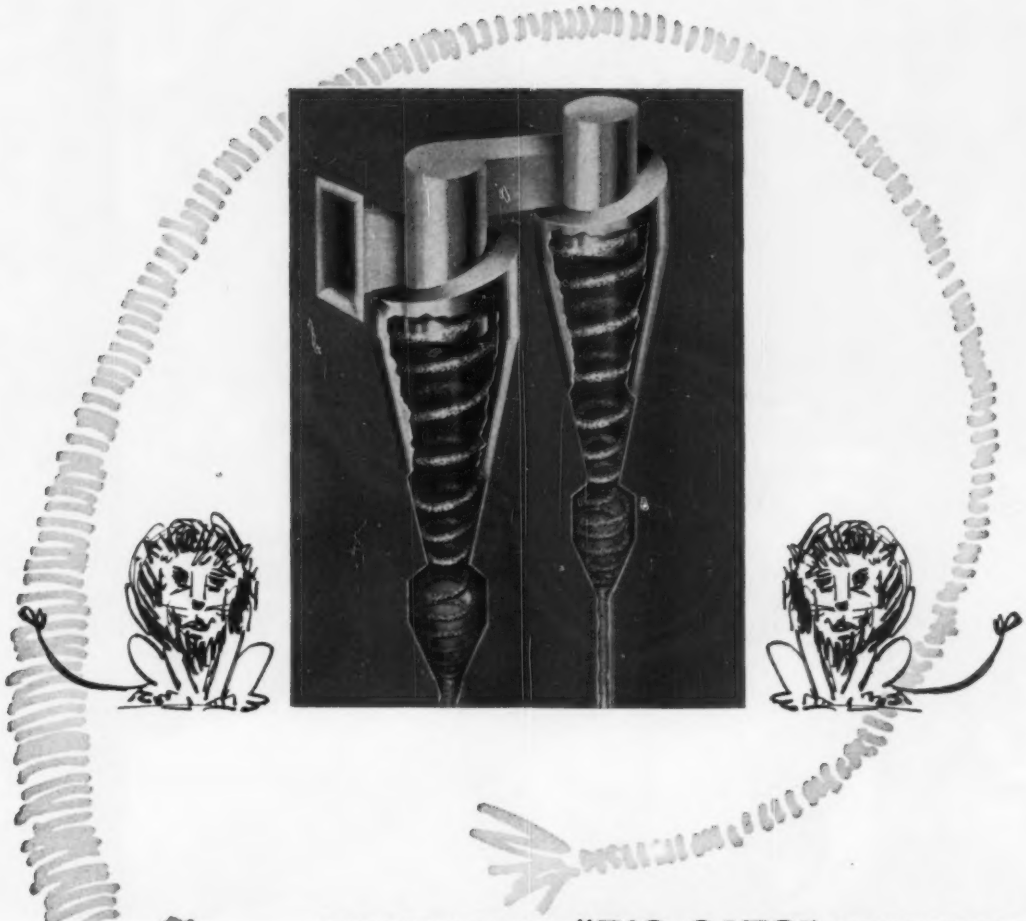

WE KEEP THE "BIG CATS" CRACKING

The "Big Cats," those steel behemoths that work wonders with the gasoline molecule, have a wild streak in them. Unless kept under control they can whip up a storm of flying catalyst dust that raises havoc with the operation and brings the Air Pollution Control people running.

To avoid this embarrassing and economically hazardous situation, refiners install our high efficiency SDC Duclones and Trickle Valves. They save money . . . improve performance . . . and in general do an admirable job. They snare each flying catalyst particle and plummet it back into the fluid bed to perform the miraculous task of catalytic cracking.

Is it any wonder that Duclones were used in two large refineries which set records for continuous on-stream service.

For more information on how SDC Duclones can keep "Big Cats" cracking, send for bulletin C-2058.

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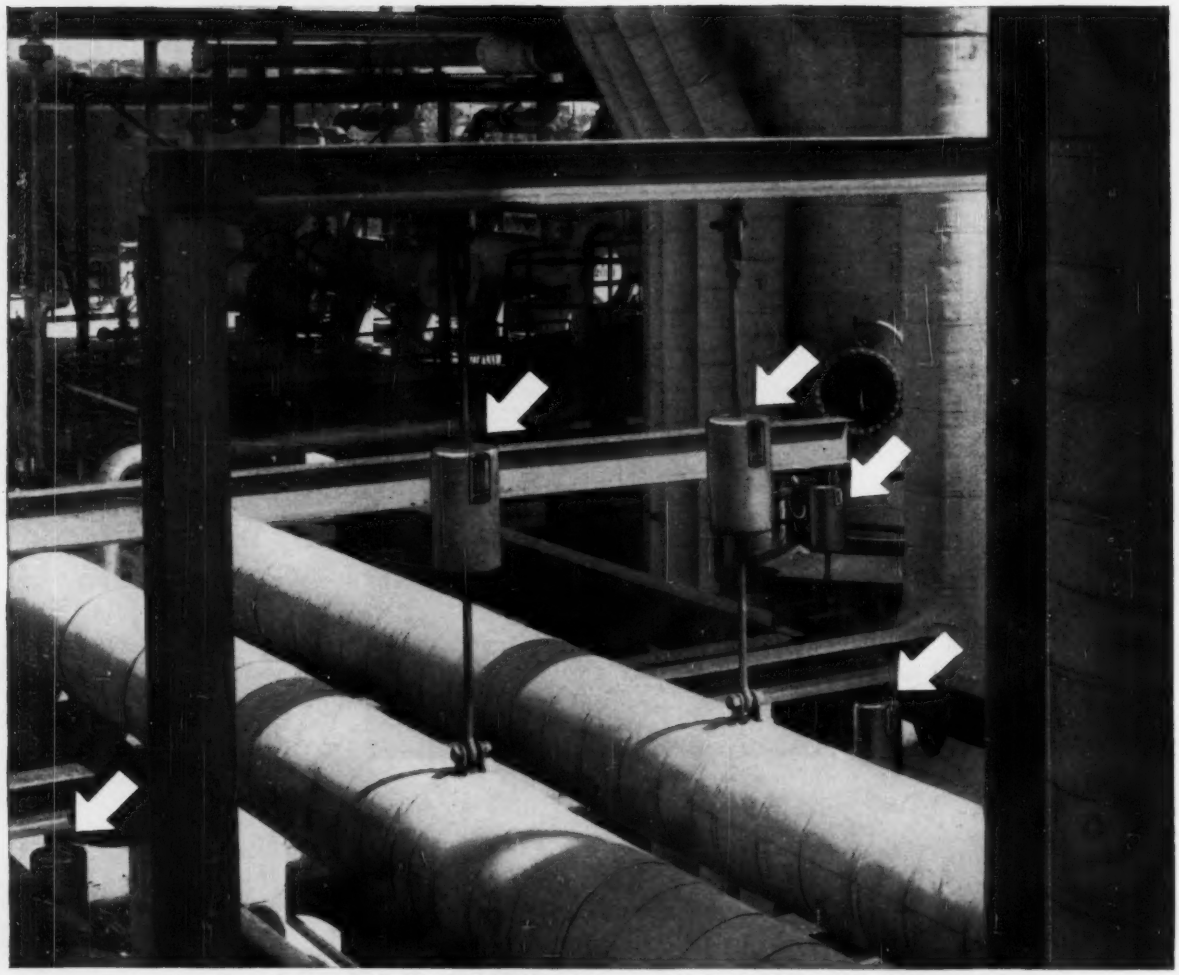
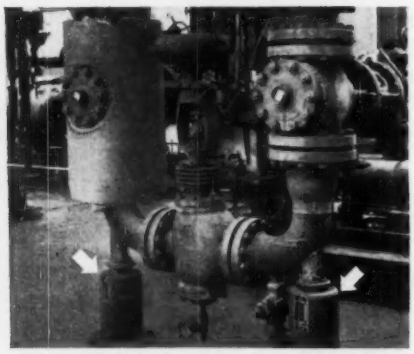


Heater feed line (r.) and return line (l.) at Sinclair Refinery show Grinnell Variable Spring Hangers at work.

Grinnell Hangers support high-temperature pipe lines at Sinclair Refinery



Grinnell Variable Spring Hangers support bottom lines on vacuum still operating at 750°F.

Hot news: Grinnell variable Spring Hangers support pipe lines at Sinclair Refining Company's Marcus Hook, Pa. plant, that operate at temperatures *above 500°F.* Yet these flexible hangers easily accommodate thermal movement in the pipe lines!

Where reactive forces at terminal points must be kept within specified limits, *Grinnell Constant Support Hangers* are recommended. Where pipe lines are subject to vertical movement and restrictive conditions do not require the use of a constant support type, *Grinnell Variable Spring Hangers* are recommended. Where abnormal horizontal movement or vibration in pipe lines must be prevented, *Grinnell Sway Braces* are recommended.

Grinnell maintains a staff of trained technicians ... provides highly skilled advice and assistance right from the design stage ... offers experienced field engineering service. Call Grinnell Company, 277 West Exchange Street, Providence 1, R. I.

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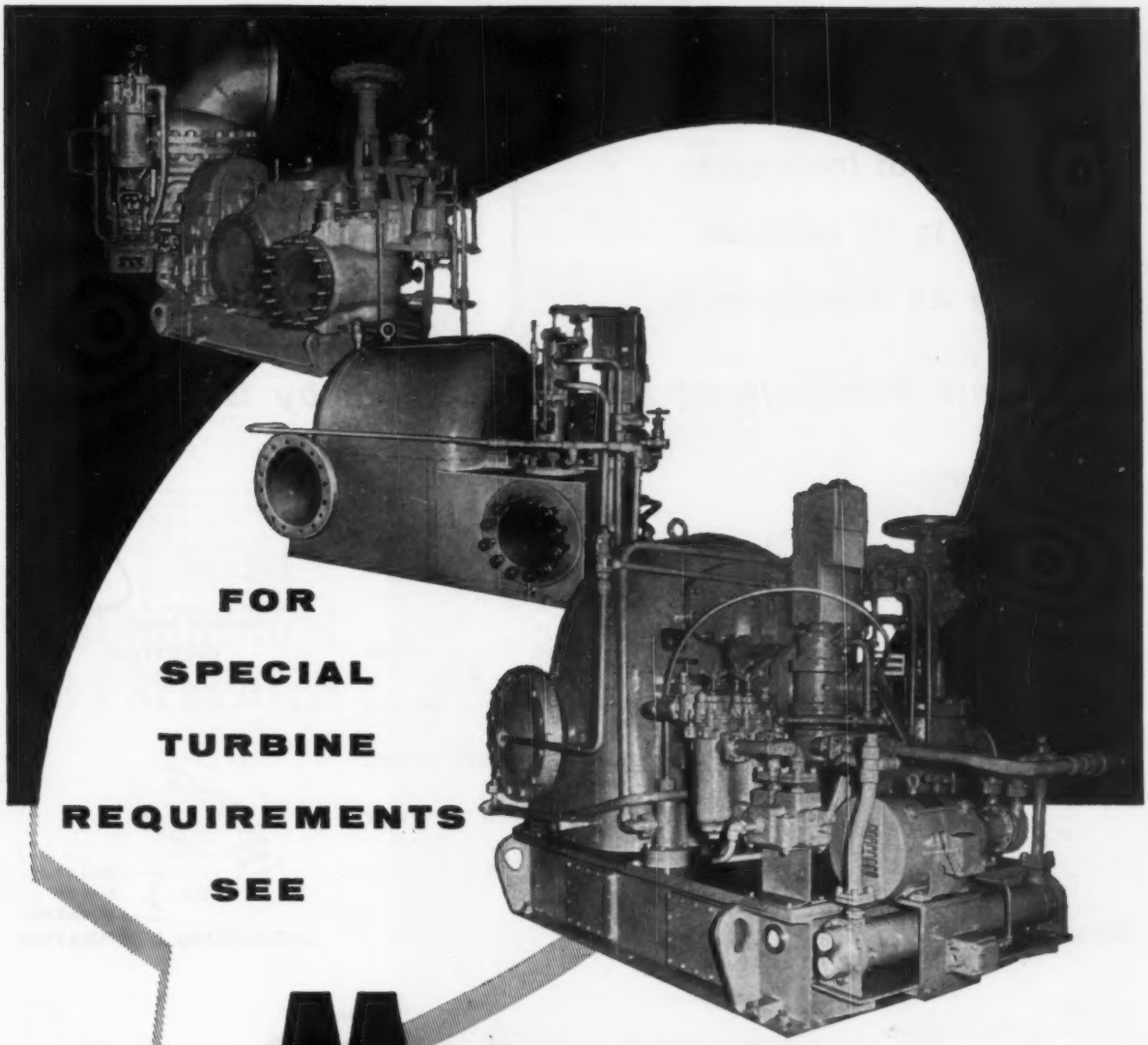

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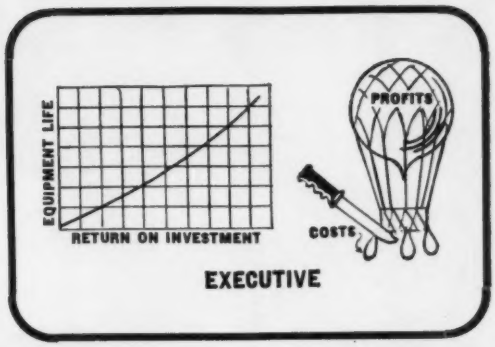

A Basic Principle of Product Design by Glitsch—

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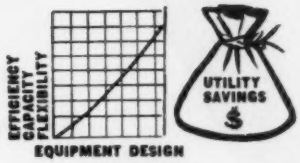
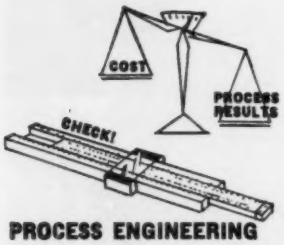
The long, useful life of Glitsch products increases the return on your investment every year. The price of Glitsch equipment makes possible the Glitsch plus-quality of product design. *The result: A reduction in your operating and maintenance costs.*



OPERATING



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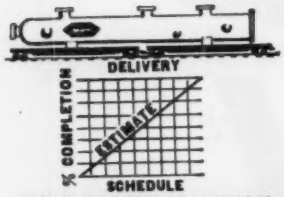

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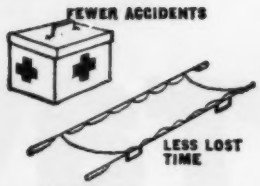

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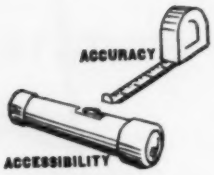

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PRODUCTS — Glitsch Lightweight "Truss-Type" Ballast Trays, Sieve, Bubble Cap, Dualflow, Disc, Donut, Accumulator, and Mist Eliminator Trays ... Pressure Vessels, Contactors, Reactors, Filters, Heat Exchangers, and Other Specialty Products ... Bubble Cap and Riser Assemblies, Flanged and Dished Heads, Machine Time, Stampings, Knitted Wire and Woven Wire Screen.

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CUT FUEL BILLS 20% WITH A LJUNGSTROM® AIR PREHEATER

The world's largest fluid catalytic cracker at Esso's Bayway Refinery is equipped with a new Ljungstrom Air Preheater. This picture shows the half-ton cold-end elements being installed in the Ljungstrom rotor.

Your biggest refinery operating expense is the money you burn: fuel costs. You can chop fuel bills ⅓ with a Ljungstrom Air Preheater, and here's how:

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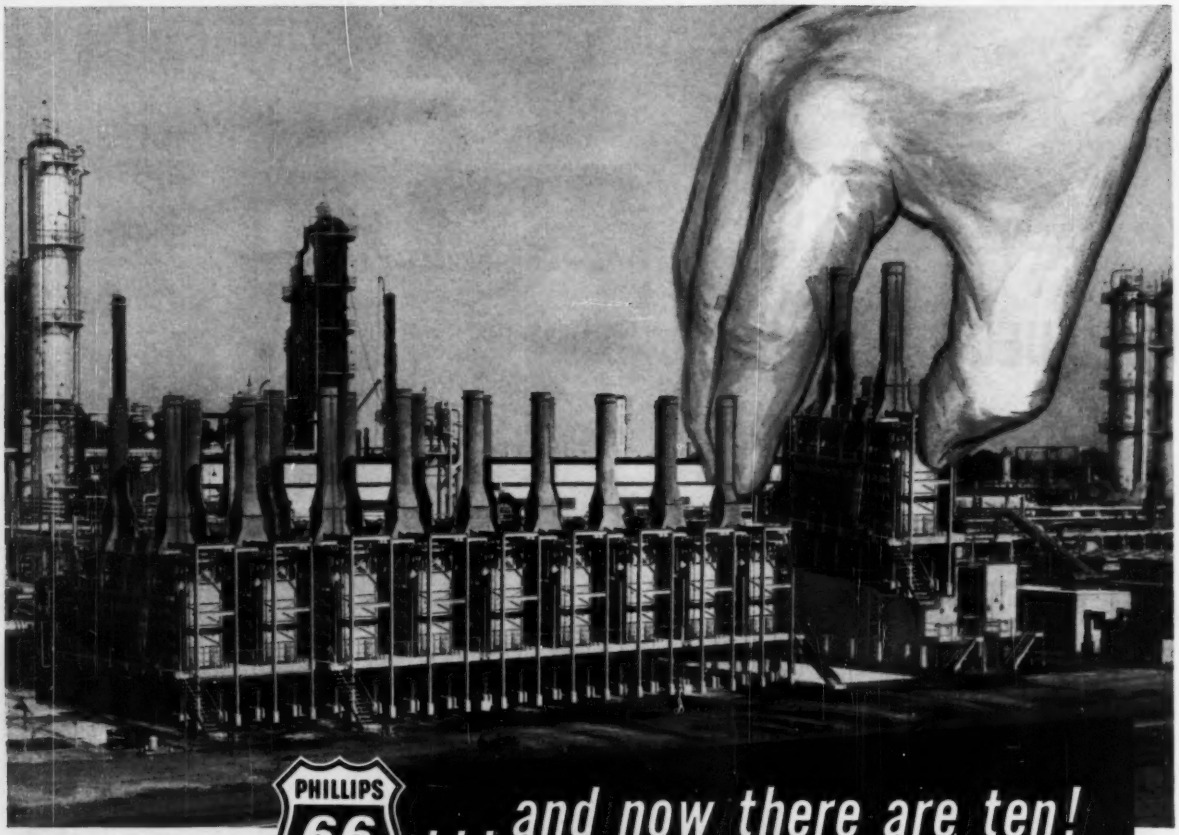

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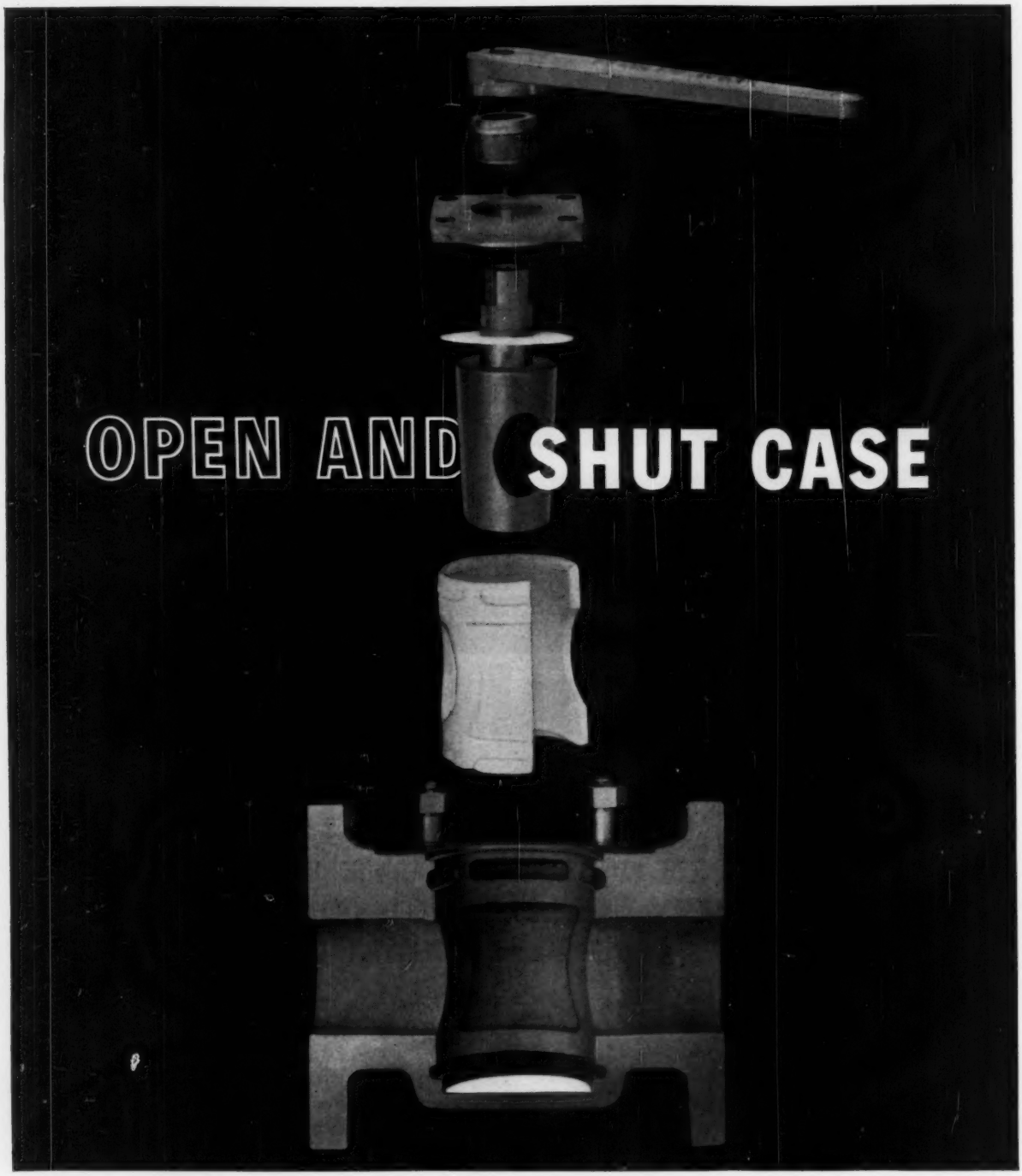

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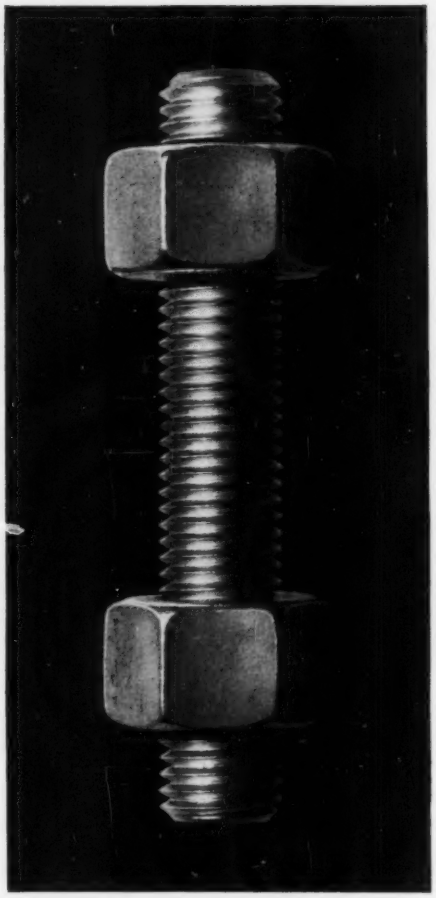

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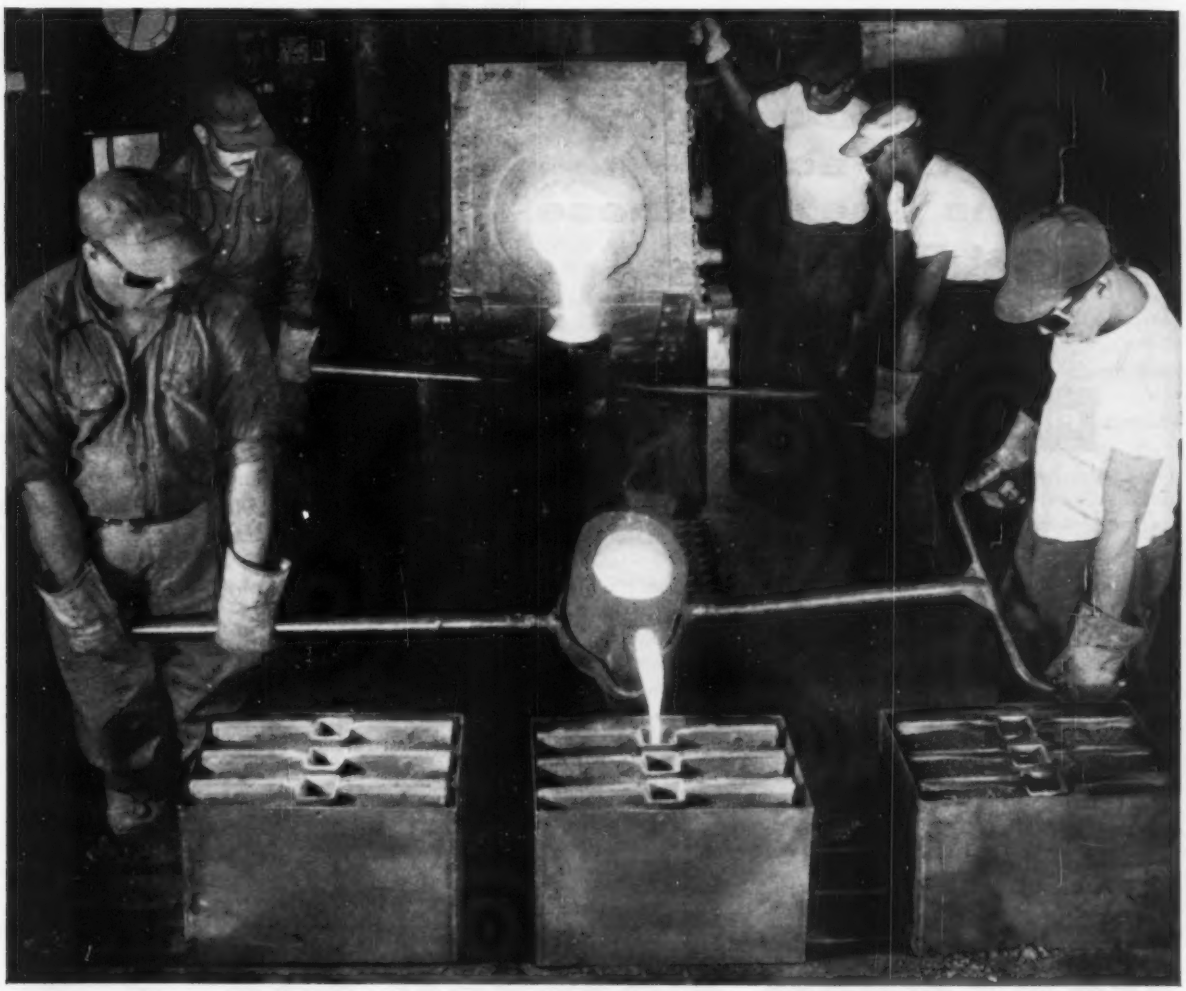

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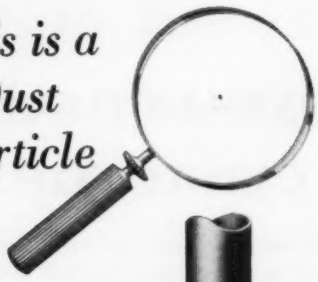

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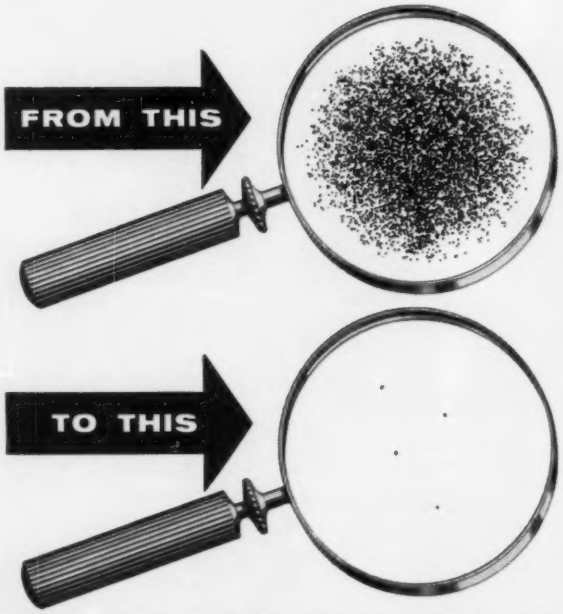

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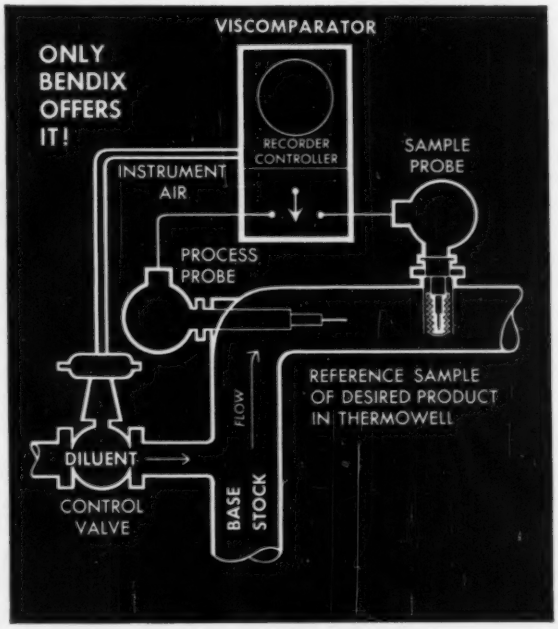

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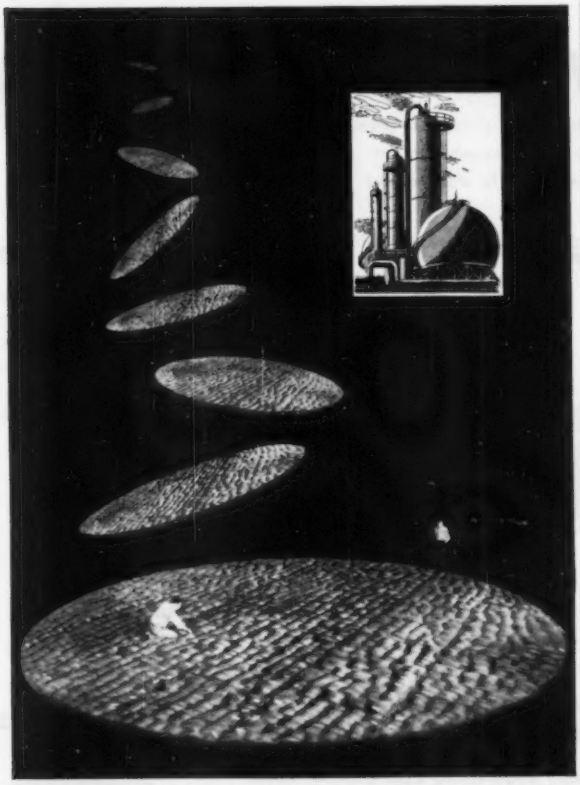

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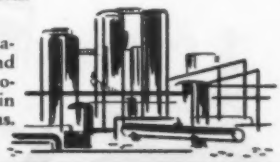

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The Mail Box...

Chart Correct, But—

To The Editor:

Please refer to the article on "Capacity of 2:1 Ellipsoidal Head" on page 328 of the September 1960 issue of PETROLEUM REFINER. The write-up near the bottom of the second column should state that coefficient C_3 is applied to the cube of the diameter, $(ID)^3$ to obtain the volume. The notation on the chart itself is correct.

H. C. Severin
California Research Corp.
Richmond, Calif.

Straight to Point

To The Editor:

May we have a copy of your "Author's Handbook"? Recently we examined a copy of this compact little booklet and found it to be "straight to the point."

Frequently we are called on to assist our technical personnel in the style approach to report writing. This book would be quite helpful as reference material in our technical library.

We will appreciate any assistance you can offer.

E. L. Kennedy, Jr., Supervisor
Training & Placement Section
Gulf Oil Corp.
Port Arthur, Texas

Editor's Note—*Copies were sent, of course. The Author's Handbook, a very helpful instrument, is available free of charge to other subscribers. Just address PR's Editorial Director, Box 2608, Houston 1, Texas.*

The Edmister Book

To The Editor:

We are particularly interested in the articles on Applied Hydrocarbon Thermodynamics by Wayne C. Edmister which we understand have been appearing in the PETROLEUM REFINER over the last two years.

However, as we do not have available the earlier issues containing these articles, we should be glad if you would inform us whether it is your intention to issue the articles subsequently in book form and when.

C. A. Montague
Planning and Economics Department
CONCH METHANE SERVICES LIMITED.
London

Editor's Note—*The Edmister articles on "Applied Hydrocarbon Thermodynamics" currently appearing in* PETROLEUM REFINER *will be available in book form some time the middle of 1961. Readers are asked to watch the columns of PR for definite announcement.*

Of "Doubtful Value"

To The Editor:

In the September 1960 issue, Page 172 there appeared a letter in your mail box from J. A. Kuntze. The letter itself is of doubtful value from a technical standpoint and I would appreciate the deletion of such material in the future issues. Then there is an error in the letter. It should read:

RULE: To change °C to °F multiply °C by 1.8 and add 32 to the product.

C. Alvin Wentz, Jr.
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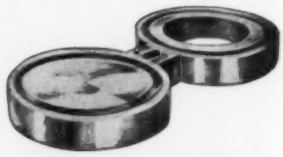

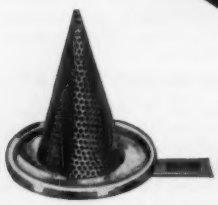

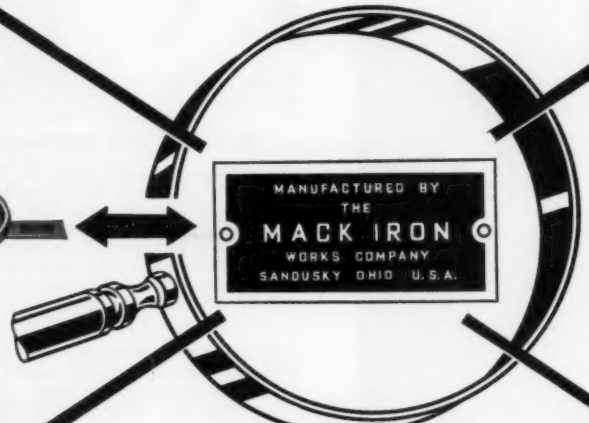

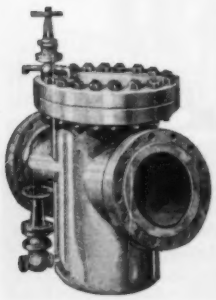

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The York Times

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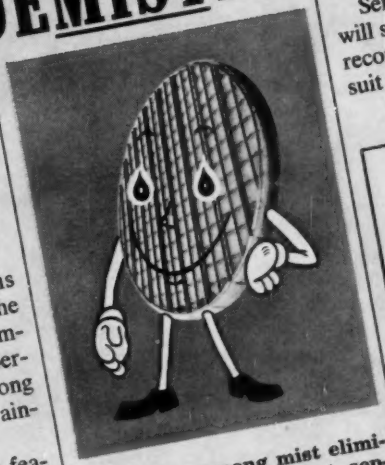
This month of elections again finds Mr. Demister, the Otto H. York symbol for improved process equipment performance, the leader among mist eliminators and entrainment separators.

Outlined below are the features behind the success of York Demisters — features which are directed to satisfy the demands of process engineers for a simple means of improving the performance and increasing the throughput capacities of liquid-vapor processing equipment — the features that are the reason for Mr. Demister's outstanding acceptance and leadership.

Efficiency — York Demisters are extremely efficient — over 99.9% — accounted for by over 100 square feet of surface per cubic foot of separator volume.



The leader among mist eliminators and entrainment separators.

Economy—York Demisters are low in cost because of the low weight of the material used.

Easy Installation — York Demisters are simply tied to a support ring in the vessel.

Low Pressure Drop — due to over 97.7% free volume in the wire mesh.

Increased Production — by permitting operation at higher vapor velocities.

Promptness — York Demisters are shipped promptly regardless of size, shape, or material of construction.

Service — York engineers will study your application and recommend the Demister to suit your needs.

The principle behind the operation of a Demister is very simple. Here's what happens: (1) As vapor disengages from liquid it carries with it fine liquid droplets. (2) When the vapor stream passes through the fine wire mesh, the liquid droplets impinge on the wire surfaces, coalesce into large drops, and fall off. (3) The vapor is now dry and free from entrained liquid.

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PETROCHEMICALS 1960

THE PETROCHEMICAL INDUSTRY continues to show remarkable growth. And this growth should keep jumping at the remarkable rate of more than 10 percent per year. Petrochemicals now account for 56.1 billion pounds or more than 30 percent of the entire annual chemical production. Their value exceeds 60 percent of all chemical sales or almost $7 billion per year.

Of the 118 new projects announced for U.S. construction in 1960, for basic and intermediate petrochemicals, at least 45 were by oil companies or joint ventures between chemical and oil companies.

Behind this expanding growth of an industry, which now accounts for more than 80 percent of all organic chemicals, are some interesting facts. It's not all due to new products, although admittedly some of the older products have been modified and improved to be classed almost as new products. Behind all this scurry of activity are better and more complex processing techniques, greater abundance of higher purity raw materials, better catalysts, as well as instrumentation and automation improvements.

These changes in technology have kept older products growing and these new tools have helped older products meet consumer demand with little added processing costs. Even with the newer polyethylene and polypropylene films—that old standby cellophane keeps growing. The standard of the synthetic rubber industry—SBR—is now made in more than 100 varieties and enjoys increasing growth, even as the newer synthetic natural rubbers come on the market.

Plastics stand out from the group. These petrochemicals bear the torch for extensive growth prospects. In this Petrochemical Developments issue you will notice several pages devoted to polyolefins. This is as it should be because experts predict that by 1965 plastics production will reach 8.1 billion pounds annually.

This year has seen some remarkable announcements in petrochemical plant expansions. Styrene plants projected will add 450 million pounds to the current annual production capacity of 1,500 million pounds. Synthetic rubber expansions amount to 196,000 long tons. Polyolefins capacity should jump some 450 million pounds before the middle of 1961.

All this expansion is not confined to the U.S. Rather the growth is world wide. Canada is struggling to meet its current petrochemical demand of 500 million pounds with a prospective demand by 1965 of more than 2 billion pounds. Latin America has reported plans which will put Mexico into the petrochemical business in a big way. Brazil and Argentina are getting some more large petrochemical complexes.

European growth has been nothing short of spectacular. More than $1.2 billion in new plants have been announced for France, Germany, Italy, Netherlands and Britain. Japan already is being recognized as a growing source of petrochemicals and Australia and the Far East are planning and building new plants.

Petrochemicals are continuing their remarkable record of growth and the outlook is indeed bright.

OUR INDUSTRIAL ADVISORS for the 1960 Petrochemical Developments Issue are shown above, left to right: Francis Olmsted, U.S. Industrial Chemicals Co.; Melvin J. Astle, Case Institute of Technology; Franklin Veatch, Standard Oil Co. (Ohio); David J. Porter, Diamond Alkali Co.; Thomas E. Corrigan, Ohio State University; Robert C. Binning, Monsanto Chemical Co.; Luther R. Hill, M. W. Kellogg Co.; and Tom Ponder, Petrochemicals Editor. These experts pointed out important developments and guided us in our search for material included in this issue.*

Thomas C. Ponder
PETROCHEMICALS EDITOR

* The attendance by executives, engineers, superintendents or other employes of petrochemical companies at these conferences does not constitute an endorsement of PETROLEUM REFINER over any other publication. The fact that men of outstanding ability are allowed to attend these planning conferences shows the interest which companies have in sound editorial content for the benefit of the industry.

A SPECIAL REPORT

Polyolefin Processes Today

Here's an extensive review of the state of the art in polyolefin resin processes. Based on an extensive patent and literature search, this comprehensive article brings you up to date on just where polyolefins stand today

Marshall Sittig
Princeton, N. J.

POLYOLEFIN PLASTICS are now a billion pound-per-year business. They are major consumers of petroleum raw materials and have wrought revolutions in squeeze bottles, packaging films, electrical insulation, plastic pipe and other industrial and consumer products.

Polyethylene

Polyethylene, the first and still the greatest of the polyolefin plastics, is the result of a series of accidental discoveries. It was discovered in 1933 by Imperial Chemical Industries in England. The discovery was made inadvertently in the course of an attempt to react ethylene with benzaldehyde in an autoclave. A thin film of a white waxy solid was the first high-pressure polyethylene. Some years later, a chemist named Max Fischer working in the laboratories of the I. G. Farben-industrie was attempting to synthesize lubricating oil from ethylene using aluminum powder and titanium tetrachloride as catalysts; he obtained a solid white mass as a coproduct with the lubricating oil—the first low-pressure polyethylene. In similar fashion, Phillips Petroleum Company and the Standard Oil Company of Indiana carried out work originally directed at turning ethylene into motor fuels and synthetic lubricants; in each case the work evolved into a new process for the production of solid polyolefin resins. Still another accidental discovery was that made by Karl Ziegler in Germany; Ziegler, unlike Fisher, however, was quick to realize the significance of his discovery and to capitalize on it.

Polyethylene is an exceptionally important material of commerce. It is a thermoplastic, normally solid material which usually melts at temperatures above 110° C and which shows, by X-ray diffraction analysis, the presence of a crystalline phase. It is essentially a polymer of ethylene of high molecular weight, usually 15,000 to 40,000 or higher, with controlled and limited branching and cross-linking of the polymer chains.

Polyethylene has exceptional insulating qualities in electrical applications and finds important use in such fields, particularly where high frequency currents are involved, as in radar. Because of its flexibility at ordinary temperatures and its wide transition range, polyethylene is used in the molding of a large number of articles such as toys, kitchen utensils, and the like.

Polyethylene may have a tensile strength of 2,000 psi or higher and a tensile elongation of 300 percent or higher. Large quantities of polyethylene film are used for packaging.

By using special reaction conditions and a particular series of catalysts, higher-density ethylene polymers having molecular weights substantially in excess of 10,000 and softening points substantially above the boiling point of water (115° C or even higher) are produced. Such polymers are particularly desirable in the plastic and resin molding industries because of the physical and structural stability of articles molded therefrom at temperatures above the boiling point of water, making it possible to sterilize such articles with hot water or steam. Thus, such articles as combs, baby bottles, containers for infants' food, surgical tubing and other articles can be fabricated from these improved polymers. These products are also more desirable from the standpoint of stiffness and hardness and possess substantially greater tensile strength. These properties are apparent in the production of molded parts which are subjected to mechanical wear such as roller bearings, cams, and gears.

Conventional polyethylene sold for 35 cents per pound in 1959 and dropped to 30 cents in 1960 with a 2½ cent-per-pound discount for orders of more than 20,000 pounds.

Polypropylene

Highly isotactic polypropylene possesses a unique set of properties of its own. It is the lightest plastic known (sp. gr. = 0.90); it is resistant to temperatures up to 300° F; it has good dielectric properties, even at high frequencies; it has good impact strength at room temperature and above; resistance to chemicals is excellent

and permeability to gases is low; its abrasion resistance is superior. These physical properties combine with the fact that it can be readily processed in many ways (by molding, extrusion, vacuum-forming, casting, welding, or machining) to give easily-colored articles of wide utility in the trade.[321]

In contrast to polyethylene, polypropylene possesses much greater potentialities as a fiber-forming material. Polypropylene for use as a fiber compares quite favorably with other known fibers. Polypropylene with a molecular weight of 40,000 to 50,000 corresponds to nylon with a molecular weight of 10,000 to 20,000 as far as properties of the fiber are concerned. The density of the polypropylene is low, the fiber can be spun dry, no solvents or plasticizers are needed, and its lower melting point facilitates spinning, according to Stille.[358]

Polypropylene is selling for 42 cents per pound in 1960. This represents a considerable decrease from its introductory price, which was 63 cents per pound. It was successively reduced to 56 cents, to 48 cents (in late 1958), then to the present level which is currently 7 cents above the price level of high-density polyethylene.

Polymers of Higher Olefins

Poly-l-butene combines outstanding resistance to stress cracking with good cold flow characteristics and high burst and tear strengths. This combination of properties indicates application for poly-l-butene in plastic pipe and in film form when the newest of the polyolefins enters full-scale commercial production.

As pointed out in the next section, development of other polymers of higher olefins, as well as copolymers of higher olefins with ethylene, are doing much to broaden the tremendous commercial vistas already opened by polyethylene. These vistas spell opportunity for the petroleum and petrochemical industry—both in monomer production and in polymer manufacture, the latter alone or in combination with established resin producers or fabricators.

The Scope of This Survey

THIS REVIEW has been made in an effort to provide timely coverage in one of the most dynamic growth fields in industry today. It brings up to date the coverage afforded by earlier reviews by Kropa and Stickney,[347] by Gordon,[328] by Thomasson, McKetta and Ponder,[359] by Burk and Strain,[324] by Aggarwal and Sweeting,[318] by Raff and Allison,[352] by Stille,[358] and by Gaylord and Mark.[327] Further, since the field is expanding at such an explosive rate, this review—while timely—will undoubtedly be subject to further revision in the near future. Since the technology in the field is highly competitive and is subject to a complex pattern of patent coverage, emphasis has been put on the patent literature. Although patent coverage may not be truly representative of commercial practice, it gives the best and indeed the sole insight into commercial polyolefin processes at this time. This article covers patents issued through March 1, 1960.

Within the patent area, coverage has been confined to U.S. patents. This has been done to make the original references easily readable by the average reader if he cares to refer to them. It also avoids the duplication which may be inherent in citing patents from different foreign countries; presumably the fact that a U.S. patent has been granted eliminates duplication of other U.S. patents. It is realized that there is a lag between a patent application on a new process development and the granting of a patent but it is felt that this may roughly parallel or even anticipate the lag in putting that development into commercial practice. Thus, while a patent survey such as this may be somewhat outdated in terms of today's research, it is probably representative of the state of the industry and may describe developments which are not yet in full scale operation.

This review is confined to solid (rather than liquid or viscous) polymers and concentrates on resins rather than on the lower molecular-weight waxes. It is also confined to homopolymers of the aliphatic mono-olefins (which excludes polystyrene and diolefins) plus some copolymers of the olefins with other olefinic hydrocarbons; it specifically excludes copolymers with oxygenated compounds such as maleic acid, ethers, methacrylates, vinyl esters, etc. This does not mean to minimize the importance of such oxygen-containing copolymers for special uses but does try to confine this review to a coherent group of materials of major importance.

This review excludes isobutylene polymers since they are viscous masses or rubbers rather than resins.

The coverage of this review is further limited to the process starting with the olefin raw material and concluding with a purified polymer. Thus it includes catalyst recovery, solvent recovery and attendant steps between olefin and polyolefin. However, it excludes any polyolefin chemical conversion processes such as chlorination or sulfochlorination; it excludes incorporation of additives, such as antioxidants, to the polymer; it excludes any mechanical polymer forming operations such as molding, extrusion, etc.

Further, the preparation of aluminum alkyls from basic raw materials such as aluminum, hydrogen, olefins and alkyl halides, while an important adjunct to some olefin polymerizations, is not discussed here. However, admixture of these aluminum alkyls with other compounds to produce the actual complex metal catalysts will be considered here. The preparation of metal oxide catalysts will not be discussed here when catalyst preparation is not directly related to an olefin polymerization process.

In this review, for the first time, an attempt has been made to portray some of the engineering aspects of polyolefin processes—to show details of reactor construction, heat removal, process control, and polymer recovery. Most other coverage to date has been more from the standpoint of the organic or polymer chemist rather than the practicing chemical engineer, petroleum refiner, or petrochemical operator.

The patents considered here fall largely under Class 260 in the Patent Office Classification system (Chemistry, Carbon Compounds) and more specifically in subclasses

88.1 Hydrocarbon polymers
88.2 Copolymers

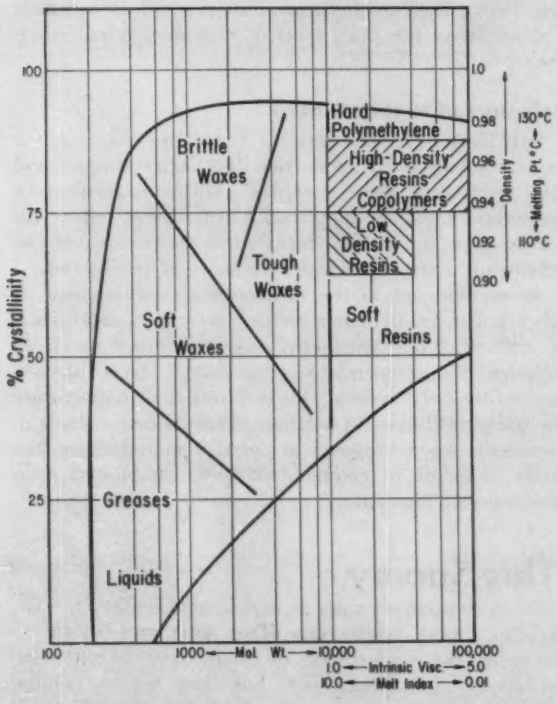

FIGURE 1—In the overall spectrum of polyethylenes, shown as molecular weight versus percent crystallinity, only the shaded portion will be covered in this article.

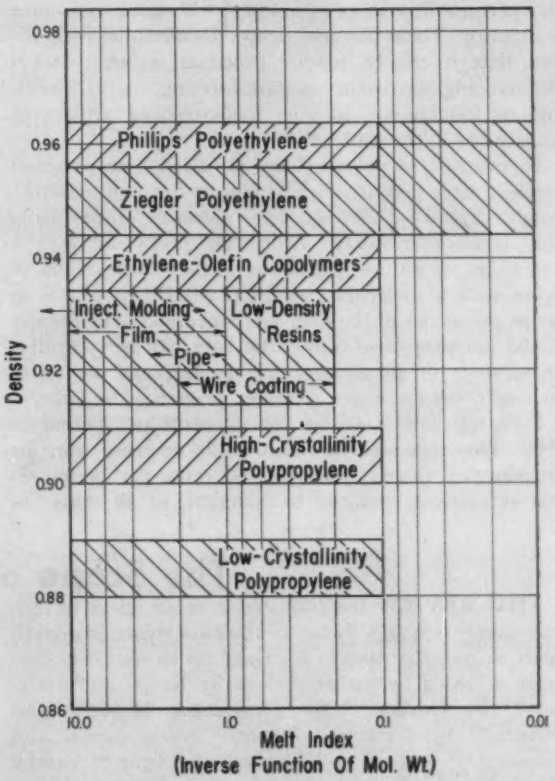

FIGURE 2—A closer look at the resin area covered in this article shows the position of various commercial materials plotted with density versus molecular weight in terms of melt index.

93.7 Acyclic hydrocarbon polymers
94.8 Isobutylene and propylene polymers
94.9 Ethylene polymers

Figure 1 illustrates the spectrum of polyethylenes and delineates the area of concern in this review in terms of molecular weight (which governs flow properties) versus crystallinity (which expresses structure and reflects mechanical properties). Figure 2 goes a step further and defines the resin area in more detail showing the positions of the various commercial materials in a plot of molecular weight versus density. Again we have a plot of a flow property (which defines the practical processability of a resin) against a structural and mechanical property (which defines the utility of a resin). Quantitative relationships between various physical properties have been the subject of a comprehensive study by Sperati, Franta, and Starkweather.[357]

The polyolefin polymers described here can, of course, be subjected to such after-treatment as may be desired to fit them for particular uses or to impart desired properties. Thus, the polymers can be extruded, mechanically milled, blown or cast into film, molded or converted to sponges or latices. Antioxidants, stabilizers, fillers, extenders, plasticizers, pigments, insecticides, fungicides, etc. can be incorporated into the resins.

The polymers having high specific viscosities can be blended with lower molecular weight polymers to impart stiffness or flexibility or other desired properties to the latter.

The solid resinous polyolefins can be blended in any desired porportions with hydrocarbon oils, waxes such as paraffin or petrolatum waxes, with ester waxes, with high molecular weight polybutylenes, etc. They may be used as viscosity index improvers, to increase the viscosity of oils, and as gelling agents for such oils.

The polyolefin polymers can also be subjected to chemical modifying treatments, such as halogenation, halogenation followed by dehalogenation, sulfohalogenation by treatment with sulfuryl chloride or a mixture of sulfur dioxide and chlorine, sulfonation, oxidation, etc. The polymers can also be irradiated by high energy X-rays (0.5 to 2.5 mev or more) or by radioactive materials to effect cross-linking, increases in softening temperature, etc.

The Growth of Polyolefins, 1940 - 1960

THE FIRST POLYOLEFIN RESIN was polyethylene, discovered in England by workers of Imperial Chemical Industries in about 1933. By 1938, one ton of the new material had been produced. The first U.S. patent on the I.C.I. polymer[1] was issued on April 11, 1939. Thus, the real commercial beginnings of the polyolefins date from about 1940.[320]

PRODUCTION VOLUME

Even though the commercial beginnings of polyethylene in England date from 1940, the industry in

the United States (with which this article is primarily concerned) dates from 1943 in terms of substantial commercial production (of low-density resins). From 1943 to 1953, Du Pont and Carbide were the only commercial producers of such materials. The real expansion in polyethylene began in about 1955 as shown in Table 1. Similarly, the real boom in polyproplyene is just now beginning in 1960.

PROCESS TRENDS

The original I.C.I. polyethylene process operated at 500 to 3,000 atmospheres. This was one of the highest pressure processes employed by the chemical industry. From 1943 to 1956, this was the only type of polyethylene process in operation in this country.

Since 1950 much interest has centered around the so-called low pressure polyethylene processes. Actually, the Ziegler process is the only one which operates at atmospheric pressure, the Indiana process operating in the moderate pressure range from 60 to 100 atmospheres, and the Phillips process at about 30-40 atmospheres. In all of these processes, the catalyst is suspended (albeit in colloidal form, a slurry, or as pellets in a "fixed" bed) in a solvent for the ethylene. Table 2 shows the growth of these processes.

PRODUCT TRENDS

Packaging film has always been the predominant use for polyethylene, having dominated the end-use field for years as shown in Table 3. Electrical insulation held second place in polyethylene applications for years but it has encountered severe competition from other polymers (such as polyesters) and molded articles and plastic pipe now seem destined for second and third places with electrical applications in fourth place by 1962. Squeeze bottles, which usually "are" polyethylene to the general public, actually fall in sixth place in importance of polyethylene uses.

Polyethylene produced by the original high pressure process, while a revolutionary product in itself, left some things to be desired:

1. Its softening point was too low. It would not hold its shape at boiling water temperatures and could not be sterilized—limiting its markets.

2. It was too soft and flexible and did not have adequate strength for some applications.

3. Plant investment costs were high (up to $1,000 per ton of annual capacity) and high-pressure operation was not easy.

Thus the low-pressure processes (and some of the modified high pressure processes) which produced a high density product gave the property changes summarized in Table 4. The high density products, produced at lower process operating pressures, and characterized by more regularly ordered structures have also been referred to as "low-pressure" and as "linear" polyethylenes, with the "linear" designation preferred.

A patent[123] has been granted covering linear ethylene polymers having a density (annealed) in the range of 0.95 to 0.97. This patent claims new compositions of matter in the form of these polymers which were stated (as of the Aug. 2, 1951 application date) to have a higher degree of linearity than any hitherto known ethylene polymers. These materials were made by subjecting ethylene to pressures of from 5,000 to 20,000 atmospheres at temperatures from 40° to 100° C in the presence of a catalyst yielding free radicals such as an organic peroxy compound or an azonitrile. The question of the dominance of this patent over similar

TABLE 1—Production Capacity for Polyolefin Resins (in millions of pounds)

POLYETHYLENE

Producer	1953	1954	1955	1956	1957	1958	1959	1960	1961
Allied Chemical						5	25	30	100
Celanese					40	40	40	50	50
Dow			25	25	25	25	130	130	165
Du Pont	100	125	125	200	200	200	200	200	260
Foster-Grant									10
Goodrich-Gulf									15
Grace						50	50	50	50
Hercules					30	30	30	30	30
Koppers			25	25	30	40	45	45	60
Monsanto		65	65	65	100	100	100	100	100
Phillips					75	75	75	75	75
Spencer			50	50	50	90	90	90	90
Texas Eastman			25	25	25	60	100	100	100
Union Carbide	60	185	185	250	250	375	375	375	375
U.S.I.			25	45	45	100	175	300	300
Totals	160	375	525	685	870	1170	1435	1575	1780

POLYPROPYLENE

AviSun							20	20	120
Dow									40
Enjay								40	65
Firestone									10
Hercules					20	20	20	50	130
Montecatini								10	25
Texas Eastman									20
Totals					20	20	40	120	410

TABLE 2—Growth in "Low-Pressure" Process Capacity for Polyethylene

Producer	1956	1957	1958	1959	1960	1961
Allied			5	20	30	100
Celanese		40	40	40	50	50
Dow				30	30	30
Du Pont						
Foster-Grant						
Goodrich-Gulf						15
Grace		50	50	50	50	50
Hercules		30	30	30	30	30
Koppers		30	30	15	15	15
Monsanto						
Phillips		75	75	75	75	75
Spencer						
Texas Eastman						
Union Carbide		55	55	55	55	55
U.S.I.						
Totals	0	280	285	315	335	425

TABLE 3—End-Use Pattern for Polyethylene

	YEAR					1962 Predicted		
End Use	1953	1954	1955	1956	1960	Low density	High density	Total
Molded articles	21	34	60	75	105	99	120	219
Electrical	32	29	45	60	190	78	44	122
Film	45	70	115	150	330	246	101	347
Pipe	18	22	26	30	110	106	31	137
Paper coating	15	20	30	35	90	56	35	91
Bottles, tubes	6	7	9	12	45	78	26	104
Fibers					5		26	26
Miscellaneous				5	50	42	57	99
Total pounds, M	137	182	285	367	925	705	440	1145
(Exports)		12	65	140	?			

TABLE 4—Comparison of Physical Properties of Low and High Density Polyethylene

Property	Low density polymer	High density polymer
Tensile strength	Moderate	High
Yield strength	Low	High
Flexibility	High	Low
Processing temperature	Low	High
Color (natural)	Excellent	Good
Electrical properties	Excellent	Excellent
Transparency	Good	Poor
Impact strength	Very high	Good

compositions of matter produced by other processes is now the subject of litigation.

Whereas linearity is perhaps a sufficient criterion in polyethylene, a more complex molecule such as propylene introduces more complex questions of the arrangement of the molecules in space. This has given rise to the use of the word "tacticity" or order (from the Greek, "order"). Hence, there are "atactic" or disordered polymers, "isotactic" or regularly ordered polymers, and "syndiotactic" or alternately-oriented polymers. The various type of tacticity are shown schematically in Figure 3. Table 5 compares the densities and melting points of atactic and isotactic polypropylene and poly-l-butene. As shown there, isotacticity produces a fair increase in density and a sensational increase in melting point.

Copolymers

Copolymerization affords a valuable means of varying and improving the properties of homopolymers beyond the point which can be economically achieved by the conditions of homopolymerization.

The ratio of monomers in a copolymer depends on the ratio of monomers fed and also on the polymerization rates of the individual olefins. Thus, ethylene has a faster rate of polymerization than higher olefins and this must be accounted for in the ratio of monomers added to the polymerization mixture.

Copolymerization reduces the melt elasticity of the polymer formed and also reduces haze in films produced from the resin.[144, 341]

The original patent on resinous olefin copolymers was U.S. 2,200,429 by I.C.I.[3] This patent pointed out that interpolymerization with ethylene in general, leads to production of one or the other of the following types of products:

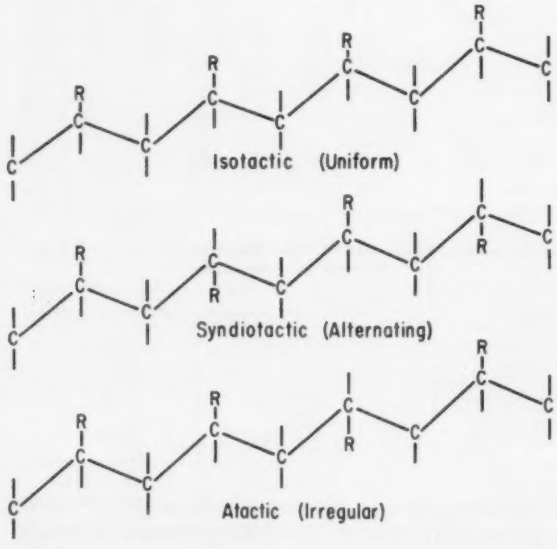

FIGURE 3—These types of tacticity or order are found in polymer chains.

TABLE 5—Comparison of Properties of Polymers of Different Types of Tacticity 240

	Atactic		Isotactic	
	Poly-propylene	Poly-1-butene	Poly-propylene	Poly-1-butene
Density	0.85	0.87	0.92	0.91
Melting point, ° C.	~80	62	165	128

a. Mixed single chain polymers. These long polymer chains in which substituent groups are interposed at various points or intervals in the normal chain of CH_2 groups.

b. Cross-linked or branched chain compounds in which single chains of the ethylene polymer type or of the mixed single chain type are linked or branched together directly or via substituent groups.

In either case, the products have properties differing from those of ethylene polymers, depending on the nature of the starting materials and on the degree of interpolymerization. Cross linking increases the melting point and decreases the solubility and processability of the polymer. Mixed single chain polymers may exhibit similar or converse effects on physical properties.

Another peroxide-catalyzed copolymerization process which has been described[95] is that in which ethylene is copolymerized with 5 to 20 percent by weight of tertiary-butylethylene in the presence of a peroxydicarbonate catalyst giving a polymer product having improved flexibility and extensibility.

The copolymer of l-butene with high density ethylene offers better stress cracking resistance and also offers better processability because it is faster molding than polyethylene. The 5000 Series of polyethylenes made by Phillips are typical of these copolymer materials. Such materials are marketed for use in the manufacture of detergent bottles and wire and cable coverings. An optimum balance between molecular weight, density, and molecular weight distribution can be struck in such copolymers to produce a very useful product.

Copolymers of propylene and l-butene are claimed to have very desirable properties.[281] Such copolymers containing 7 percent to 25 percent of l-butene have much lower brittle points than pure polypropylene. Thus 10 percent of l-butene lowers the molecular weight and lowers the brittle point to —4° C from + 13° C for pure polypropylene. It is pointed out that copolymerization of propylene with other olefins does not give similar improvement. Thus, ethylene and cyclohexene yielded polymers which were too brittle or which had lowered tensile strength or melting points.

The copolymer of propylene with large amounts of ethylene is, unlike the other polyolefins, an elastomeric material. Its properties approach those of natural rubber and in some cases are better than those of the conventional synthetic rubbers. This material has been designated C23 Rubber and its under commercial development by Montecatini in its laboratories at Milan and Ferrara in Italy. It is another outgrowth of Professor Natta's basic work on coordination catalysts formed from combinations of organometallics and transition elements. In contrast to stereospecific polypropylene, which is highly crystalline, C23 Rubber is essentially amorphous. It is a completely saturated

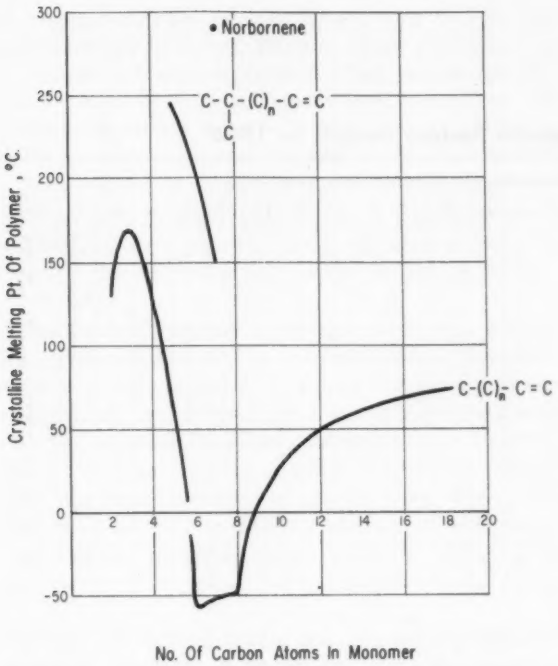

FIGURE 4—In this plot of monomer length versus crystalline melting point, notice how crystallinity gives unique physical properties to the resultant plastic.

product which reputedly possesses excellent resistance to aging and to elevated temperatures.

The copolymer of ethylene with maleic anhydride, which is specifically outside the coverage of this review, is indicative of one of the directions which polyolefins are taking to produce specialty polymers.

Copolymers of ethylene with bicyclo- (2, 2, 1) -2-heptene (norbornene) in the presence of titanium tetrachloride plus a lithium aluminum tetraalkyl have been described.[119] Such copolymers are stated to be capable of forming stiff but tough fibers and films.

Copolymers of ethylene with cyclopentene are claimed to have improved rigidity and toughness and are claimed to retain these properties better at high temperatures than ethylene-norbornene copolymers. At low concentrations of cyclopentene (below 5 percent), the stiffness of the copolymer is less than polyethylene but the toughness is significantly increased, making these materials ideal for the preparation of tough films.[188]

Higher Olefins as Raw Materials

Higher olefins are attractive as resin raw materials, in contrast to ethylene, for various reasons. Lower cost may be the incentive in the case of propylene. However, the unique properties of the resultant plastics are the main reasons. See Figure 4. Polypropylene (actually, syndiotactic polypropylene) has the highest possible melting point for a poly-n-alpha-olefin. Considered by themselves, the higher softening points may be very attractive unless the low-temperature properties are adversely affected by the substitutions to the main polymer chain. Little is known about these low-temperature properties of higher olefins except that they may show increased creep or flow under small mechanical stresses; these drawbacks are not exhibited by poly-l-butene, however.

Different types of catalysts are necessary to produce polymers of higher olefins. Many catalysts produce linear polymers of ethylene but then produce only atactic polymers of higher olefins. The following tabulation shows the yields of isotactic polymers from various higher olefins using $TiCl_3$ and $TiCl_4$ catalysts.[358]

	$TiCl_3/AlR_3$	$TiCl_4/AlR_3$
Propylene	80	40
l-Butene	65	35
3-Methyl-l-butene	90	65
l-Pentene	35	2

Chromic oxide catalyst gave only about 2 percent of isotactic polymer from higher olefins. Of the titanium halides, the trichloride and the dichloride are very effective. The tetrabromide and tetraiodide are as good or better than the tetrachloride in producing isotactic polymers, but the tetrafluoride is a poor stereospecific catalyst for polymerization of higher olefins. Titanium alkoxides, alkoxychlorides and alkyls when used in conjunction with aluminum alkyls are poor producers of isotactic polymers. Some idea of the range of monomers which can be handled by various industrial processes is given in Table 6.

TABLE 6—Monomers Handled by Various Processes

Process	Catalyst	Monomer range
I. C. I.	O_2	C_2
Ziegler	$TiCl_4/AlR_3$	C_2 - C_{16}
Indiana	Reduced MoO_3/Al_2O_3	C_2 - C_4
Phillips	Cr_2O_3/Al_2O_3·SiO_2	C_2 - C_8
Montecatini	$TiCl_3/AlR_3$	C_2 - C_{18}
Eastman	MoO_3/Al_2O_3 + RNa	C_2 - C_{10}

One of the earliest recognitions of the possibility of making solid polymers from the higher olefins was in a U.S. patent by Ziegler[78] which specified beryllium, aluminum, gallium, or indium hydrides or alkyls as catalysts for the copolymerization of ethylene with 1-butene, 1-pentene, 1-hexene, 1-dodecene and 1-hexadecene.

Bicyclo-(2, 2, 1)-2-heptene, also known as norbornene, is the condensation product of cyclopentadiene with ethylene. Solid homopolymers of norbornene which do not melt when heated to their decomposition temperature of 300° C can be prepared in the presence of a Ziegler-type catalyst.[88]

PATENT AND LICENSING ACTIVITY

Patents

The issuance of U.S. patents on polyolefin resin processes is summarized in detail in Table 7 and graphically in Figure 5. The astronomic growth of the field in the last year is emphasized both by the increase in number of patents issued and in the number of firms active in the field.

In 1959, in addition to the firms shown in Table 7, the following 14 producers appeared for the first

TABLE 7—Analysis of U.S. Polyolefin Process Patents to 1960

COMPANY	NUMBERS OF PATENTS PER YEAR																				
	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	Total
I. C. I.	1	2	..	..	..	..	1	..	..	..	..	..	1	1	..	..	..	..	..	3	2	**11**
Du Pont	..	1	..	..	..	..	6	9	2	3	8	5	1	5	1	3	1	1	2	6	15	**69**
G A F	..	..	..	..	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	**2**
Esso	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1	1	..	1	11	**15**
Carbide	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	2	2	**5**
U O P	..	..	..	..	..	..	..	..	..	1	..	..	3	1	..	..	..	..	..	..	2	**7**
Std. Oil Co. (Ind.)	..	..	..	..	..	..	..	..	..	..	3	1	..	..	1	7	17	5	5	9	16	**64**
Monsanto	..	..	..	..	..	..	..	..	..	..	..	..	1	1	1	1	1	..	..	2	2	**9**
Shell	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	2	1	1	..	..	**5**
Borden	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	..	..	..	**3**
Ziegler	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	..	..	**2**
Olin Mathieson	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1	..	..	**2**
Eastman	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	2	9	**12**
Phillips	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	13	14	**28**
Hercules	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	10	**11**
BASF	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	**3**
Dow	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	3	**5**
Callery	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	**1**
Ruhrchemie	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	**3**
Ethyl	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	**3**
Plus 31 others from 14 other producers first tabulated in 1959 (See Text)	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	31	**31**
Totals	**1**	**3**	**0**	**0**	**1**	**1**	**8**	**9**	**3**	**4**	**11**	**6**	**6**	**9**	**3**	**12**	**24**	**11**	**11**	**45**	**123**	**291**

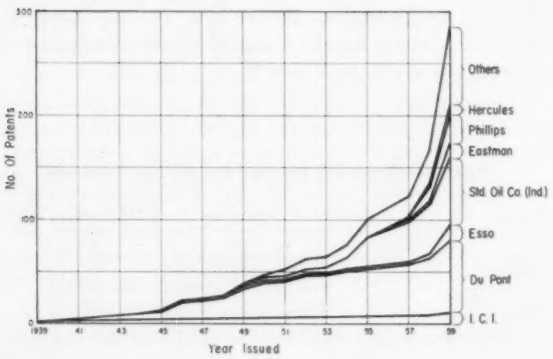

FIGURE 5—This plot of patent issuance in the U.S. emphasizes the rapid increase in the past few years as well as in the number of firms active in the field.

time. The numbers following the firm names indicate the number of patents issued in 1959:

Farbenfabriken Bayer	1	Goodrich Gulf	1
Sun Oil	11	Texaco	1
Montecatini	2	Spencer	3
Rhone Poulenc	1	Distillers, Ltd.	1
Koppers	4	National Distillers	1
Aries	2	American Cyanamid	1
Sinclair	1	Chemical Werke Huls	1

Through March 1, 1960, 26 patents issued in the area of concern to this review. This would indicate, by extrapolation, over 150 U.S. patents to be expected to issue in this field in 1960. In the first two months of 1960, patents issued to 11 firms already active in the field

Du Pont	1	Hercules	2
Esso	1	Eastman	3
Std. Oil Co. (Ind.)	2	Phillips	5
Monsanto	1	BASF	1
Ruhrchemie	1	Sun Oil	6
Goodrich Gulf	1		

and to two new entrants in the polyolefin patent derby:

Collier Carbon & Chemical	1	American Oil Co.	1

Since patents are such a vital part of the polyolefin picture and since this review is, therefore, so largely based on patents, some further information on the patent picture seems very appropriate (see box).

Licensing

Entry to the polyolefin field may be accomplished

The Patent Pitcure

U.S. PATENT APPLICATIONS total about 70,000 per year and U.S. patents granted total about 40,000 per year. Therefore, polyolefin patents are less than one-half of 1 percent of all patents granted. The number in this one really narrow technical field is still tremendous, however. The complexity of polyolefin patent technology has led the Research and Development Unit of the Patent Office in Washington, D.C., to undertake a study of the application of a computer to searching of prior art in the polyolefin field. Admittedly picking an area of technology which offers maximum challenge, the Research and Development Unit also feels that they have picked an area of maximum potential reward because if the present rate of increase holds or accelerates, the problems of manual searching will be formidable and time-consuming indeed.

It has been estimated that some $60,000 in research and development moneys are expended per patent application. About one patent results from every two applications. An inspection of Table 7 reveals that polyolefin research must have been at the rate of over $15 million per year in 1956 or 1957 (since the average patent takes 2-3 years to issue). Currently it may exceed $30 million per year.

It has also been estimated[355] that one dollar of research and development money requires ten dollars in eventual plant investment. Thus, the current estimated $30 million R & D level will generate plant investment at the rate of $300 million per year. Assuming 33 cents in plant investment per pound of annual capacity, this would mean 1 billion pounds of new plant capacity per year. Obviously, this is perhaps an order of magnitude too high but today's intense research level portends big things to come.

by research and patenting or by purchase of a license and know-how. Various companies have pursued various routes as shown in Table 8 which summarizes the licenses held by various organizations as well as the numbers of patents issued—the latter bearing some relation to original research pursued by these producers.

The cost of a complete I.C.I., process package (patents plus manual plus technical help) involved a $500,000 down payment on a cumulative series of royalties that, at the start, amount to over 8 percent of net sales.

The cost of a license to practice the Ziegler process has been reported to be several hundred thousand dollars—paid in advance. This price was for a package of know-how on catalysts and their utilization and was not an engineered process package. Thus Hercules Powder Company not only acquired a Ziegler license but also purchased production details from Farbwerke Hoechst in addition to doing complementary research in their own laboratories.

TABLE 8—Summary of Polyolefin Process Licensing

Producing Licensees	Licensor				Own patents issued 1940-59 inclusive
	Phillips	I. C. I.	Ziegler	Indiana	
Allied					0
AviSun					11
Celanese	√				0
Dow		√	√		5
Du Pont		√	√		69
Esso			√		15
Grace	√				0
Hercules			√		11
Koppers		√	√		4
Monsanto		√	√		9
Phillips					28
Spencer		√		√	3
Texas Eastman		√		√	12
Union Carbide	√	√	√		5
U. S. I.		√			1
Totals	3	8	6	2	
Non-producing Licensees					
Goodrich-Gulf			√		1
M. W. Kellogg	√				0

Licenses and full engineering specifications for the Phillips process are available on a royalty basis keyed to production—7 percent of sales for the first 5 years and 6 percent of sales for the next 13 years.

Raw Materials

RAW MATERIALS for olefin polymerization may come from a variety of sources. Thus, one patent describes a method whereby catalytic cracker off-gas containing 6 percent ethylene plus about 6 percent propylene may be subjected first to molecular sieve treatment whereby both olefins are adsorbed; the desorbed mixture is then passed over a catalyst which polymerizes propylene to liquid polymers leaving pure ethylene as a resin raw material.[238]

Table 9 summarizes some typical analyses of commercially available olefins.

TABLE 9—Analysis of Commercially Available Pure Olefins

Constituent	Ethylene	Propylene	1-Butene
Ethylene	99.6%	0.0%	
Propylene	< 0.02%	99.5%	
1-Butene			98.0%
Methane	0.1%		
Ethane		100 ppm	
Propane		0.5%	
n-Butane			0.6%
Isobutane			
2-Butene			0.8%
Isobutylene			0.6%
Acetylenes and dienes	15 ppm		5 ppm
Oxygen	4 ppm	6 ppm	1 ppm
Carbon dioxide	12 ppm	6 ppm	10 ppm
Carbon monoxide	< 1 ppm		5 ppm
Water	2 ppm	25 ppm	20 ppm
Sulfur	1 ppm	4 ppm	5 ppm
Nitrogen		10 ppm	

ETHYLENE

Production

The current production of ethylene for chemical uses is nearly 5 billion pounds annually and the potential availability of ethylene from refinery operations far exceeds this figure.

The major sources of the ethylene produced today are as follows:

1. Cracking of propane
2. Cracking of ethane
3. Separation from refinery off-gas
4. Cracking of heavier hydrocarbons

Details of these processes are outside the scope of this review. The reader is referred to the recent PETROLEUM REFINER article by Davenport[330] as a timely introduction to ethylene technology.

The consumption of ethylene for polyethylene manufacture has grown from 6 million pounds in 1945 to 1230 million pounds in 1960. By 1965, it will reach nearly 1.8 billion pounds, it has been estimated. As of 1960, consumption in polyethylene manufacture accounted for 25 percent of all ethylene produced.

Purity

One of the critical points from the polyolefin resin producer's standpoint is ethylene purity. Figure 6 shows the steps in the preparation of 99+ percent ethylene.

The oxygen content of commercial ethylene may be 1500 ppm (0.15 percent) and this is not a suitable feed material for many polyethylene processes.[7]

De-oxygenation of ethylene to improve its utility as a polymerization process feed material may be accomplished by passage over a reduced copper catalyst or by fractional distillation of commercial ethylene. Either of these methods can reduce oxygen content of the ethylene to betwen 10 and 20 ppm and with care can effect a reduction to 5 ppm.[7]

Treatment under pressure with molten sodium at about 150° C may be employed[39] to reduce the oxygen content of ethylene below about 10 parts (by weight) per million.

Dehydration to less than 0.1 weight percent water and deoxygenation to less than 10 ppm oxygen can be accomplished by sequential passage of the olefin charge stock through copper granules (reduced copper oxide) and then through beds of highly adsorbent silica gel or similar solid adsorbent.[74]

Organometallic catalysts of the Ziegler-type are sen-

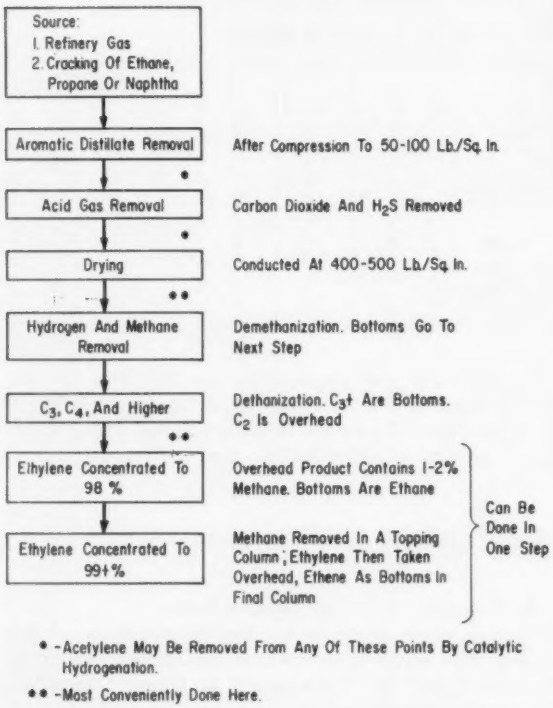
Source:
1. Refinery Gas
2. Cracking Of Ethane, Propane Or Naphtha
Aromatic Distillate Removal
After Compression To 50-100 Lb./Sq. In.
*
Acid Gas Removal
Carbon Dioxide And H_2S Removed
*
Drying
Conducted At 400-500 Lb./Sq. In.
**
Hydrogen And Methane Removal
Demethanization. Bottoms Go To Next Step
C_3, C_4, And Higher
Dethanization. C_3+ Are Bottoms. C_2 Is Overhead
**
Ethylene Concentrated To 98 %
Overhead Product Contains 1-2% Methane. Bottoms Are Ethane
Ethylene Concentrated To 99+%
Methane Removed In A Topping Column; Ethylene Then Taken Overhead, Ethene As Bottoms In Final Column
Can Be Done In One Step
* -Acetylene May Be Removed From Any Of These Points By Catalytic Hydrogenation.
** -Most Conveniently Done Here.

FIGURE 6—These typical steps in the preparation of 99+ percent ethylene shows the critical problem from the polyolefin resin producers' standpoint of ethylene purity.

sitive compounds which react easily with oxygen, CO_2, moisture and other substances and are decomposed thereby. One way of purifying olefin feeds prior to introduction to such catalysts is by pre-treatment of the olefins with the same or similar organometallics.

Thus 0.5 to 1.0 percent of trialkyl aluminum may be heated with the ethylene as a means of purification.[78] Similarly, zinc alkyls can be used to remove all undesirable materials except CO_2. This pre-treatment may even be conducted directly in the reaction vessel prior to the induction of the main portion of catalyst.

Volatile oxygenated organic compounds can be removed by

- passage through adsorptive alumina, silica gel, or the like;[74]
- contacting with a suitable hydrocarbon solvent such as benzene, xylene, higher boiling aromatics, or paraffinic solvent boiling from 100 to 300° C. Contacting is carried out at 15 to 100° C and 15 to 2000 psi pressure.[74]

PROPYLENE

While the potential availability of propylene from refinery operations has been huge—and of about the same magnitude as ethylene availability—total chemical uses of propylene account for slightly more than 2 billion pounds of propylene annually as of 1960.

About 95 percent of the propylene produced today is in the form of refinery off-gas with the balance produced as a co-product of cracking operations for ethylene manufacture. Of the nearly 20 billion pounds of propylene thus produced, about 15 billion are converted to gasoline by alkylation and polymerization.

The propylene industry is undergoing a rapid change with the increasing demand for larger quantities of higher purity product for polypropylene manufacture. Before 1958, the percentage of propylene going into polypropylene was nil. As of 1960, about 53 million pounds out of a total 2259 million pounds of propylene were estimated to have gone into polypropylene. By 1965, it is estimated that 420 million pounds will go into polypropylene out of a total of 3054 million pounds expected to be consumed in all chemical uses.

Ethylene-propylene copolymers may be produced and an unreacted mixture of ethylene and propylene recovered and recycled in the scheme shown in Figure 7. Ethylene, propylene, and propane are fed to a recovery system; fractionation is used to remove most of the ethylene as an overhead product. The bottoms from fractionation go to an adsorber where the propylene is adsorbed. The propylene is desorbed, mixed with the ethylene and recycled to the reactor.[205]

1-BUTENE

Total C_4 hydrocarbons constitute one of the major refinery by-product streams. These streams are mixtures of n-butenes, iso-butylene, n-butane, and isobutane. The major sources of 1-butene are

1. Separation from the butane-butene fraction
2. High temperature cracking of naphthas and heavier stocks
3. Direct dehydrogenation of butane.

The problem at this point is one of separation of pure, or relatively pure, olefins. The total volume of 1-butene plus 2-butene produced for chemical uses is in excess of 3 billion pounds; this exceeds total propylene consumption for chemical uses. The butylene growth curve forecast for 1960-65 is not as steep as those forecast for ethylene or propylene, however.

It has been stated that for the production of poly-1-butene, purity of the monomer must be "well above" the 95 percent 1-butene which is commonly commer-

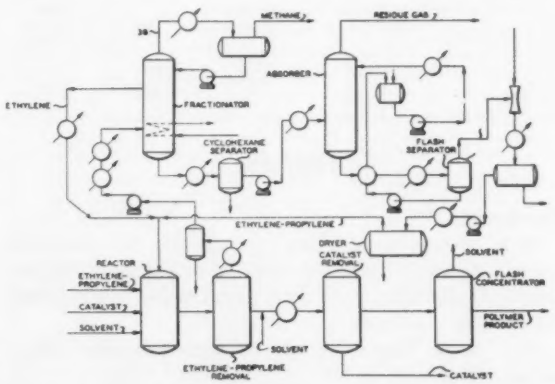

FIGURE 7—Ethylene-propylene copolymers may be produced and the unreacted mixture of ethylene and propylene recovered and recycled in this process scheme.

cially available as of 1960. The 95 percent material is, however, adequate for incorporation to the extent of 5 percent in ethylene-butene copolymers.

HIGHER l-OLEFINS

Production of higher l-olefins is more potential than actual at this time. Mixed pentene and hexene streams are available from petroleum processing and pure l-pentene, for example, can be separated by fractional distillation.

As one progresses to higher olefins, one finds mixed olefin streams available.

- C_7 olefins from the mixed polymerization of propylene and butylene.
- C_9 olefins from the trimerization of propylene (at the current rate of 100 million pounds per year).
- C_{12} olefins in the form of propylene tetramer (at the rate of 500 million pounds per year).
- C_{16}-C_{20} olefins from the dehydration of fatty alcohols.
- Higher l-olefins from ethylene oligomerization.

However, many of these olefins have undesirably branched chains for polymer production. Further, as the carbon chain length goes up, the number of isomers increases greatly and the separation of the desired olefin becomes more complex and more expensive.

CYCLO-OLEFINS

Bicyclo - (2, 2, 1) - 2 heptene, the Diels-Alder condensation product of cyclopentadiene with ethylene is a monomer of considerable interest. It produces homopolymers stable to 300° C.[88]

Process Characteristics

FACTORS WHICH govern polyolefin resin processes include temperature, pressure, reaction time, as in the case of most petrochemical processes. Beyond that familiar trio of variables, we find that the solvent or reaction medium exerts a particularly significant effect in these polymer processes. Reactor design and heat transfer are of course important considerations to permit effective control of the basic variables. The most important process variable is catalyst choice but discussion of that problem will be reserved for succeeding sections of this review.

TEMPERATURE

Increasing the temperature generally decreases the molecular weight of the polymer produced. By raising the temperature, the ratio of the rate of the termination reaction to the rate of the polymerization reaction is increased, thereby reducing the average chain length of the polymer and making it possible to control the molecular weight through temperature.[166] In order to make temperature control operative in this manner, however, it is necessary to operate at a temperature high enough to keep both monomer and polymer in solution.

Temperature also affects polymer structure. It has been found that the rate of atactic polymer formation is relatively insensitive to temperature, whereas the rate of isotactic polymer formation is slow below 80° C but increases rapidly above that temperature. At 60 to 80° C, the isotactic polymer is formed at low and uneconomic rates but comes out of solution as easily handled granules. At temperatures above 80° C, the rate of isotactic polymer formation increases further but the polymer is stringy and adherent.

On the other hand, Stille[358] reports that a study of polymerization temperatures and temperatures during catalyst preparation reveals that the highest degree of stereospecificity is obtained at low temperatures, usually 0—30° C.

PRESSURE

The rate of polymerization increases in a more or less linear manner with pressure. The molecular weight of the polymer also increases with pressure.

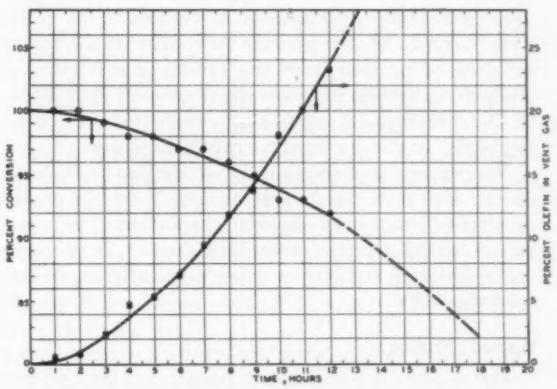

FIGURE 8—Notice the effect of reaction time on conversion and olefins in the vent gas for the Phillips process.[162]

Low-pressure olefin polymerization processes, however, have a number of advantages over higher pressure processes in

a. Lower equipment cost
b. Greater operating safety
c. Greater adaptability to continuous processing.

REACTION TIME

Polymerization times in various polyolefin resin processes may vary from a few seconds to several hours depending on the batch or continuous nature of the process. The contact time or space velocity employed is selected with respect to temperature and other process variables, catalysts, the specific type of product desired, and the extent of olefin conversion desired in any given run or pass over the catalyst.[71]

The effect of reaction time on percent conversion and on percent olefins in the vent gas in the Phillips process is shown in Figure 8.[163]

REACTION MEDIUM

Polymerization of diolefins has traditionally been conducted in emulsion form; aside from some early work, emulsion polymerization is insignificant in olefin polymerization, however. Vapor phase operations have

not achieved a significant place in commercial operations either. Dense phase or liquid phase operations have been important in high pressure processes. The most important technique as of 1960 involves the use of liquid media which act both as solvents for the monomer and polymer and as a suspending medium for the catalyst. The future may bring other developments—including even possibly solid-state polymerization as a new route to crystalline polymers.

The use of tertiary butyl alcohol as a polymerization medium in the high pressure process has been described.[34] Improved polymer properties (clarity, strength, and extrudability) are claimed for products produced at 20° to 400° C and 50 to 3,000 atmospheres using peroxy compounds, oxygen, hydrazinium compounds or N-chloroarylsulfonamides as catalysts in the presence of the tertiary butyl alcohol medium.

Dimethylneopentylcarbinol is claimed[124] in proportions from 10 to 200 percent by weight of the reactant ethylene to be free from any serious interference with the polymerization reaction when polymerizing ethylene in the presence of diperoxy-dicarbonate ester, dialkyl peroxide, or azo-bis-isoalkyl nitrile catalysts.

Neopentane is claimed to be a reaction medium and carrier liquid in which polyethylene forms in granules or similar small-sized discrete shapes that can readily be separated from a reaction mixture in a process using peroxide catalyst or other free-radical producing substances.[126]

Vapor Phase

There are very few vapor phase catalytic processes for olefin polymerization to solid polymers. A number of patents state that solvents are not necessary, but are desirable.

A dry-phase process has been patented, however.[306] As shown in Figure 9, it involves mixing recycled powdered polymer with catalyst solution to give a dry powder. This powder is fed by screw conveyor to a jacketed reactor operated by 60° C.

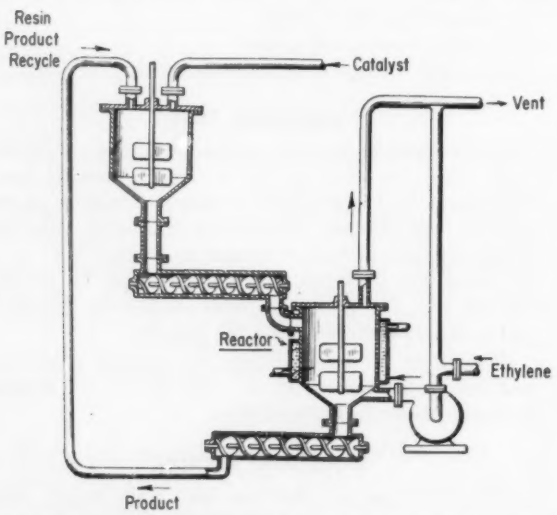

FIGURE 9—In this dry-phase process,[306] recycled powdered polymer is mixed with catalyst solution to give a dry powder and fed by a screw conveyor to the reactor.

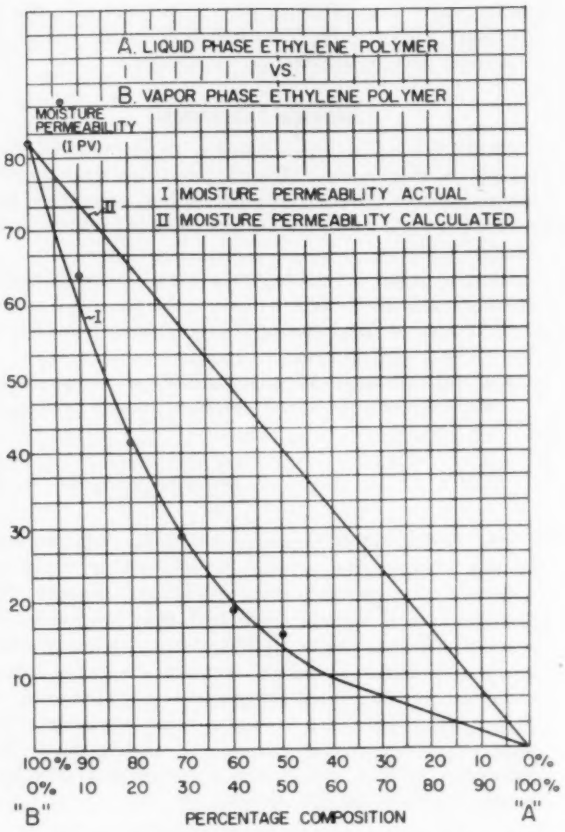

FIGURE 10—Notice how ethylene polymer produced in a liquid phase process has higher moisture impermeability than that from the vapor phase process.

Liquid Phase

Operation of ethylene polymerization processes below the critical temperature of ethylene, 9.6° C, is claimed to have several advantages:[107]

1. It avoids the need for using costly high pressure equipment
2. It produces polymers with a high degree of linearity, density, and crystallinity (density of 0.976)
3. It forms films possessing a high degree of moisture impermeability (See Figure 10).

Useful catalysts cited for this process include peroxygen compounds (preferably promoted by metals), aliphatic azo compounds or metal alkyls (activated by certain metals). It may be proper to question, in this instance, whether the moisture permeability is improved by liquid phase operations or by the use of catalysts which produce high density polymers.

The I.C.I. bulk process (operated at 375° F and 1500 atmospheres) is stated by Thomasson, McKetta and Ponder[359] to give a polymer with higher dielectric strength and better optical clarity than polymers made by I.C.I. processes operating in the presence of water or benzene plus water.

The polymerization of ethylene using Alfin catalysts is preferably conducted in the liquid phase,[61] according to the patent literature.

Solution

It has been stated[39] that solution polymerization offers a number of difficulties. It is difficult to procure ethylene solutions containing a desirably high concentration of ethylene. Also, when ethylene is polymerized in solution, the rate of ethylene polymerization is relatively unaffected by the pressure under which the polymerization is conducted; this is disadvantageous and indicates rather strongly that the limiting factor in the rate of ethylene polymerization in solution is the relatively slow rate of dissolution of ethylene in the solvent.

However, these disadvantages are outweighed in most cases by the desirable functions of such solvents. A summary of the functions that solvents may perform in polymerization processes using solid catalysts includes the following:

1. Solvent for the olefin—bringing it into contact with the catalyst and/or the growing polymer chain.
2. Protector for the catalyst—protecting the growing polymer chain from chain breakers such as impurities in the feed stock, polymer already formed on certain parts of the catalyst surface, etc.
3. Viscosity reducer—reducing the viscosity of the solid polymer on and within the catalyst and thus facilitating the process of transferring olefin where it is needed. In slurry processes, the solvent functions in dispersion of catalyst particles and assists agitation, particularly in the latter stages of polymerization.
4. Polymer remover—dissolving the polymer from the catalyst surface.
5. Catalyst control helping to establish the valence level of the catalyst (see below).
6. Reaction promoter—makes possible a gas liquid interface in which the growing polymer chain may be oriented and from which it may react with olefin supplied from solution or gas phase.[75]

In the production of polyethylene over solid catalysts, an important requisite is the use of an efficient solvent that will remove the polyethylene as formed, so as not to reduce catalyst activity. As pointed out by Peters, Zletz and Evering,[351] solvents studied in work on the Indiana catalysts varied widely in their ability to dissolve polyethylene and, further, apparently affected the specific viscosity of the polymer produced. Especially with nickel-charcoal catalysts, a lower molecular weight polymer was formed; the solvent seemed not only to dissolve the polyethylene but seemed to act as a reducing medium that established the valence level of the catalyst system. This reducing action of hydrocarbons can be easily observed with vanadia and chromia catalysts; in the presence of paraffinic solvents under reaction conditions, they undergo color changes that indicate reduction to a lower valence state.

Suitable solvents include aromatics and aliphatics including diesel oil, hexane, heptane, cyclohexane, tetralin, decalin, benzene, and ortho-dichlorobenzene. In some cases oxygenated compounds such as di-n-butyl ether, dioxan, or tetrahydrofuran can be used.

Molten petroleum waxes can be used as polymerization media,[81] producing directly a dispersion of polyethylene in the wax which is useful as such in paper coating, etc. Also, molten polyethylene itself can be employed as the solvent-diluent in ethylene polymerization.[111]

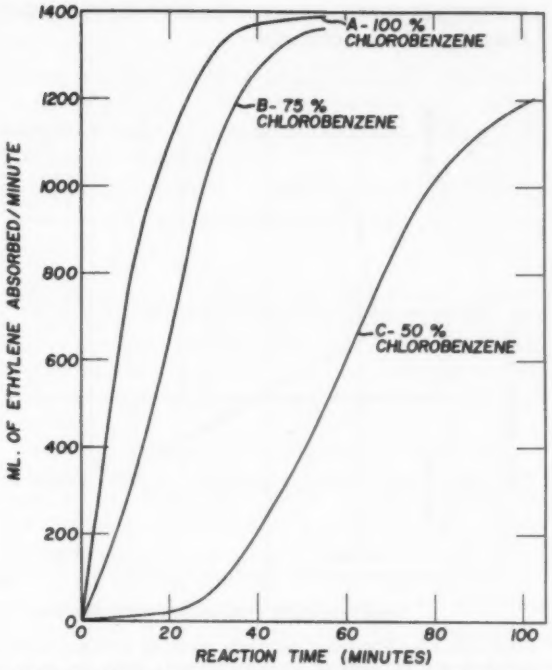

FIGURE 11—Reaction time, when using a Ziegler-type catalyst in a paraffinic solvent, can be reduced by chlorobenzene.

Aromatic hydrocarbons are not desirable solvents for use in the Phillips process because they diminish catalyst activity. In the Indiana molybdena process, aromatics do not exert such an undesirable effect on catalyst activity, but they are alkylated under the reaction conditions—by ethylene, and even more readily by propylene. Thus, a non-alkylatable solvent such as decalin is often preferable. According to Gaylord and Mark,[337] even liquid olefins such as normal hexene, cyclohexene, or substituted butenes or hexenes may be used as solvents in the Indiana process; this indicates that, in contradistinction to the Phillips process, the Indiana catalyst does not produce polymers from C_6-olefins.

In the Phillips process, 1-3 mole percent of ethane are always specified as present in polyethylene manufacture, along with over 90 percent solvent and 3 percent ethylene; in some "solvent-less" versions about 25 percent ethane and 75 percent ethylene are the materials charged. In polypropylene manufacture over the Phillips process, 10-25 mole percent of propylene are fed, along with 75-85 percent isopentane and 5-15 percent propane; in some few cases, 25 percent propylene and 75 percent propane were the only materials fed. In ethylene-propylene copolymerization, 2.5-5.0 percent of the mixed olefins are fed along with 90-95 percent isooctane and 0-5 percent propane.

Chlorobenzene is claimed to have particular virtues in many olefin polymerization processes. An exception is the Indiana molybdena/alumina catalyst process where chlorobenzenes are classed as less desirable sol-

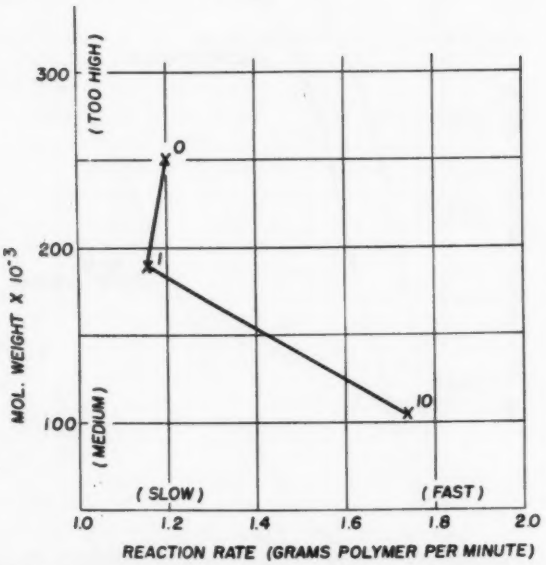

FIGURE 12—Non-polar solvents, such as perfluoromethylcyclohexane, in normal heptane reduces both the reaction time and production of excessively high molecular weight polymer. Numbers beside curve indicate percent of diluent added to ordinary solvent.

vents.[74] Thus, chlorobenzene, ethylene dichloride, and carbon tetrachloride are claimed as solvents in a process using oxygen or peroxide catalysts, which can be operated at the relatively low pressure of 100 to 300 atmospheres and at temperatures of 55° to 180° C.[5]

Aromatic or chlorinated aromatic hydrocarbons are claimed to confer particular benefits on polymer produced by polymerization under the influence of ionizing radiation.[193] Xylene in particular tends to minimize cross-linking in such a process and produce a processable polymer.

Chlorobenzene is claimed[218] to eliminate the 30 to 60 minutes sometimes encountered in the operation of a Ziegler-type catalyst in a paraffinic solvent. See Figure 11.

Admixture of from 1 to 30 percent of a non-polar solvent such as perfluoromethylcyclohexane in 99 to 70 percent of normal heptane results in both increased reaction rate and a controlled lowering of excessively high molecular weight in using a Ziegler- or Natta-type catalyst.[263] This combined effect is shown in Figure 12.

Other more exotic solvents may be used. Thus, silicon tetrachloride may be used.[292] It has the virtue of being useful both as a solvent in the polymerization step and also in subsequent polymer treatment steps, such as chlorination or chlorosulfonation.

Solvents may be purified prior to introduction to the reactor by one of the following methods:

1. Acid treatment, e.g., with *p*-toluene sulfonic acid, sulfuric acid, phosphoric acid
2. Treatment with aluminum chloride or other Friedel-Crafts catalysts
3. Treatment with maleic anhydride
4. Treatment with alkali or alkaline earth metals, their hydrides or aluminum hydrides
5. Hydrogenation or hydrofining[180, 266]
6. Filtration through a column of copper grains or Group VIII metal
7. Pretreatment with an olefin polymerization catalyst in the absence of the olefin.
8. Combinations of two or more of the above.

Solvents once used in the polymerization process must be re-purified before re-use. This involves removal of any traces of catalyst or of oxygen compounds. This may be accomplished by HCl treatment followed by washing and drying; by steam treatment followed by drying; or by distillation. Alternately, acid (sulfuric or phosphoric) treatment, or treatment with such reactive materials as aluminum chloride, maleic anhydride, or alkali or alkaline earth metals or hydrides may be used.

The solvent used in the Ziegler-type process can be purified before re-use by treatment with air in combination with water, acid, or alkali.[264] In fact, solvent regenerated by this means is said to be actually better than freshly-distilled solvent.

Emulsion

The peroxy-catalyzed aqueous emulsion technique for olefin polymerization has never been widely applied commercially. This is in contrast to diolefin polymerization where the bulk of the synthetic rubber produced during World War II and since has been produced by an aqueous emulsion process.

Various drawbacks of the emulsion polymerization of ethylene have been pointed out.[39] It is difficult to secure emulsions having desirably high ethylene concentrations. Moreover, ethylene emulsions in aqueous liquids are inherently unstable and a very considerable amount of agitation is necessary to maintain ethylene emulsions even under high ethylene pressures. In addition, some of the desirable catalysts for the polymerization of ethylene are insoluble, or sparingly soluble, in water which gives rise to the problem of adequately contacting the ethylene with the catalyst in an efficient manner.

Ethylene polymerization can be carried out in an emulsion process, however, and this technique has received considerable research attention.

Kline[346] has given a lengthy description of the emulsion polymerization of ethylene, and the process has been described in various U.S. patents.

Homopolymers of ethylene may be obtained by the emulsion technique[6] at pressures of 800 to 1,500 atmospheres, temperatures of 60 to 150° C. The ethylene is shaken or agitated with water containing an emulsifying agent (such as a sulfonic acid), a polymerization accelerator (such as an acyl peroxide) and, if desired, polymerization regulators (such as aliphatic aldehydes). A 48-hour reaction period was employed in one example. Polymer was recovered from the emulsion by the usual technique (for emulsion polymers) of coagulation with an electrolyte.

Conduct of an emulsion polymerization is described in a Du Pont patent[13] which claims reaction in the presence of water containing an alkali metal persulfate plus a reagent or buffering agent which will hold the pH in the range of 7.0 to 11.0. Pressures of 50 to 3000 atmospheres and temperatures of 40 to 350° C are specified. The quantities of persulfate employed are 0.01 to 0.6 percent based on the water used.

Use of higher percentages of an alkali persulfate, from

3 percent to about 20 percent, is claimed in a subsequent Du Pont patent.[31] An interesting feature of this latter process is the formation of a surface active agent *in situ*—that surface active agent consisting of a low polymer of ethylene (3 to 30 ethylene units) terminated on at least one end by an $-OSO_3Na$ group provided by the alkali persulfate present. Pressures of 200 to 1,000 atmospheres and 65°-200° C are specified.

However, emulsion polymers of ethylene made in the presence of persulfates are not flexible enough for most purposes and have relatively poor mechanical properties and flow characteristics. It has been claimed[48] that these problems may be lessened by emulsion polymerization in the presence of both an ionic emulsifying agent and a water soluble salt of a carboxylic acid polymer having a molecular weight above 300. The process is carried out at 120° to 250° C and at 800 to 2,000 atmospheres. Preferably from 1 to 3 percent by weight of the water soluble carboxylic acid salt and between 0.8 and 2.0 percent by weight of an organic sulfonic acid or derivative thereof are used. The process may be carried out in the presence of such ethylene polymerization catalysts as oxygen, peroxides, or azo compounds. In addition to producing polymers with improved properties, the emulsions themselves are stated to have increased resistance to creaming during storage. A more general variation of the same type of catalyst is described in another patent, also by Imperial Chemical Industries.[56] Instead of limiting the description to a water soluble salt of a carboxylic acid polymer having a molecular weight above 300, this latter patent specifies 1 to 2 percent of a "non-ionic" agent plus 0.8 to 2.0 percent of an organic sulfonic acid or derivative thereof. The non-ionic agent is of the class consisting of polyvinyl alcohol, hydrolized polyvinyl acetate polymers, cellulose alkyl ethers, the fatty acid esters of mannitol and sorbitol, and the monoethers of polyethylene and polypropylene glycols. The use of the broader nonionic agents is also claimed to permit emulsion preparation at temperatures above the softening points of the polymers.

Emulsion polymerization of olefins in the absence of any added chemical catalyst may be carried out by applying an electric potential to 2 electrodes immersed in the aqueous emulsion.[90] Since the aqueous medium is electrically conductive, the applied potential causes electrolysis of the aqueous medium. Voltages from 1.5 volts to 5,000 volts or more may be applied.

PRESENCE OF MODIFIERS

Certain substances can be added to olefin polymerization reactors to change polymer molecular weight, independent of temperature or catalyst, and afford an additional degree of control in commercial operations. Thus, oxygen, hydrogen, alcohols, and alkyl halides can all be used to reduce molecular weight, but frequently at considerable cost both in reaction rate and yield.

Oxygen. In the water-peroxide catalyzed polymerization of ethylene, the higher the oxygen content of the ethylene feed, the lower the rate of reaction and yield of polymer, the lower the intrinsic viscosity of the polymer obtained, and the higher the catalyst requirements of the reaction.[19]

The use of oxygen together with reaction time to control polymer melt index in Ziegler-type polymerizations has also been described.[127, 133]

Hydrogen. The effect of added hydrogen (expressed in terms of percent based on ethylene monomer) on the molecular weight of Ziegler polyethylene is shown in the following tabulation:

Mole % Hydrogen	Intrinsic viscosity of polymer
0.0	34.4
0.3	33.3
0.9	25.4
2.5	20.9

The effect of hydrogen on the high pressure process has been described.[18] A soft paste-like product was obtained when 0.5 to 2.5 percent of hydrogen by weight based on ethylene feed was employed; this was in contrast to the hard, tough product obtained in the absence of hydrogen.

The use of hydrogen in conjunction with azo catalysts has been patented[173] for production of polymers of density exceeding 0.930 from ethylene at high pressures.

It is pointed out by Gaylord and Mark[337] that hydrogen has an effect on propylene polymerization ten times as great as that on ethylene polymerization. Great reductions in molecular weight are effected by hydrogen in polymerization of propylene and higher olefins.

Hydrocarbons and Halohydrocarbons

Any haloalkane containing at least one bromine or chlorine atom is capable of reducing the molecular weight of a Ziegler-type polymer. Amounts of haloalkane amounting to about 1 percent of the diluent may typically be employed.

The use of cyclohexane as chain transfer agent in the high pressure process is claimed to permit control of polymer density independent of melt viscosity (and stiffness) of the polymer.[55] From 0.05 percent to 15 percent of cyclohexane is used based on the weight of the ethylene. The reaction is preferably carried out in the presence of water and/or an inert solvent such as chlorobenzene or tertiary butanol. Other reaction conditions specified include a temperature of 150° to 200° C and a pressure from 1,200 to 2,000 atmospheres. The cyclohexane controls chain growth and gives a high density (0.925 to 0.950) polymer of high stiffness which, at the same time, has a melt viscosity low enough to permit rapid and satisfactory molding.

The use of from 0.01 to 5.0 percent by weight of ethylene of a chain transfer agent such as hydrogen, carbon tetrachloride, or chloroform is prescribed for use in a solvent-free, free-radical catalyzed polymerization process giving polymer products having densities of 0.925 to 0.950.[146]

The use of hydrocarbons containing an acidic hydrogen atom (cyclopentadiene, fluorene, indene or triphenylmethane) are effective control agents[266] in processes using preformed subhalide catalysts.

Carbon Monoxide and Carbonyl Compounds

Carbon monoxide and carbonyl compounds have been claimed as valuable modifying agents for olefin polymers.

Addition of from 0.05 to 5.0 moles of an aliphatic ketone per mole of ethylene is claimed to give polymer which will extrude to clear, transparent films and, secondly, higher density polymers which are especially suit-

able for molding. Less than 10 percent of the amounts of ketones actually react under the process conditions of 1,700 to 2,400 atmospheres pressure and 160° to 225° C temperature in the presence of an oxygen or peroxide catalyst.[172]

It is particularly interesting to note that polyethylene resins prepared in the absence of added CO or carbonyl compounds[1] have a carbonyl content below 0.075 carbonyl groups per 1,000 carbon atoms. Ketone-modified polymers[172] contain 0.2 to 0.8 carbonyl groups per 1,000 carbon atoms.

The incorporation of aldehydes or ketones in alkali metal-titanium tetrachloride catalyst mixtures to the extent of 3 to 6 percent by weight of the alkali metal has been patented.[185] The $TiCl_4$/Na/ketone mole ratio may be about 1/2/0.10.

The addition of 0.005 to 5.0 percent of an aldehyde to ethylene in the high pressure polymerization process using azo or peroxy catalysts gives polymers having densities of 0.93 to 0.95 as compared to polymer densities of 0.91 to 0.92 which were obtained in the absence of the aldehyde.[207] Smaller amounts of adehydes are deleterious and higher amounts give waxy polymers having low softening points.

Other Modifiers

A number of agents have been patented which increase the melting point of ethylene polymers and, in addition, frequently increase the yield. Thus the use of one part of a phenol per 10 parts of peroxide catalyst has been claimed,[49] as has the use of a para substituted aniline,[50] or of a beta-thioethyl substituted carbonyl compound.[52] These various modifiers have been proposed for employment at pressures from 15 to 500 atmospheres and at temperatures at least as high as the initial decomposition temperature of the peroxide used as the catalyst (115° for tertiary butyl perbenzoate). Contact times of at least 10 minutes are preferred and a liquid hourly space velocity of 0.1 to 10 is cited. Peroxide catalyst concentrations of 0.1 percent to 4.0 percent based on ethylene charged are specified. The reaction is to be carried out in the presence of an inert diluent (ethylene-to-diluent ratio = 1:1) such as tertiary butanol, benzene, or cyclohexane.

Hydrogen chloride may be used as a molecular weight control agent in the Ziegler process.[260]

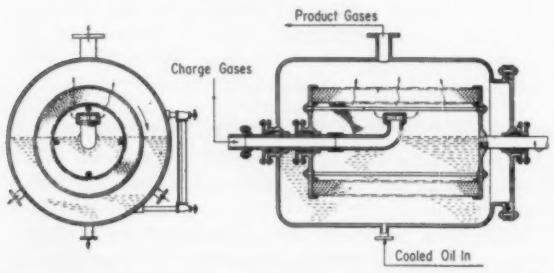

FIGURE 13—This rotating reactor permits constant polymer extraction from the catalyst.

REACTOR DESIGN

Reactor Types

1. Pipe line reactor.[158] This was the type employed in the first oxygen-catalyzed high-pressure processes which still represent a large percentage of installed capacity.

2. Ball-mill reactor.[203] Where comminution of the catalyst is important, ball-mill reactors may be used.

3. Fixed-bed.[130] This type is well-known in petroleum reforming operations carried out over platinum or molybdenum catalysts.

4. Fluidized bed.[164] This type is well-known in both fluid cracking and fluid hydroforming reactions in the petroleum industry.

5. Moving bed.[130] This type is well-known in petroleum cracking operations in the form of Thermofor or Houdriflow reactors.

6. Stirred autoclave. Although a very common type, this design has some disadvantages. One is that the centrifugal action of the stirrer causes polymer buildup much as snow drifts build up. Further the residence time of a particle compared to the theoretical average residence time may vary from 100 to several thousand percent. Particular adaptations of the stirred autoclave have, however, been developed. One utilizes a high velocity streamlined flow pattern to maintain a monomer and polymer suspension in a non-solvent medium.[159] Another is a so-called continuous autocave in which the ratio of polymer to unreacted ethylene is held constant. This is done by providing end-to-end mixing such that the feed mixes instantaneously with the autoclave contents and that the discharge stream is of constant composition. Such vigorous agitation[213] holds the temperature difference between any two points in the autoclave below 5° C. Such operation cuts the required catalyst concentration to 3 percent or less of that required in an autoclave having a non-constant environment, it is claimed.

Stirred autoclaves, particularly for laboratory use, frequently employ magnetically-actuated stirrers to eliminate packing gland problems.

7. Revolving fixed-bed.[42] This reactor as shown in Figure 13 was patented for use in a Fischer-Tropsch process. The rotating horizontal catalyst drum dips into a solvent bath. The original concept was to remove waxes from a Fischer-Tropsch catalyst in this way, but several Standard Oil Co. (Indiana) patents cite this device as suitable for the conduct of olefin polymerization and for the removal of polymer from a solid oxide catalyst. Gas enters at the trunnions and passes out through the annular catalyst bed. Good temperature control is claimed and, further, the space velocity may be controlled by controlling the extent to which the catalyst is immersed in the liquid solvent bath.

8. Alkylation contactor. This type of reactor, long familiar from its use in olefin alkylation processes for gasoline manufacture, has been suggested for use in polyolefin resin manufacture.

9. Boiling-solvent tower-type reactor.[190] A design in which catalyst flows downward counter-current to ethylene rising upward in a boiling solvent (e.g., pentane) medium is shown in Figure 14. The depth of the liquid above the ethylene feed point is 4 times the equivalent tower diameter. Solvent is introduced below the ethylene feed point, effecting catalyst removal from

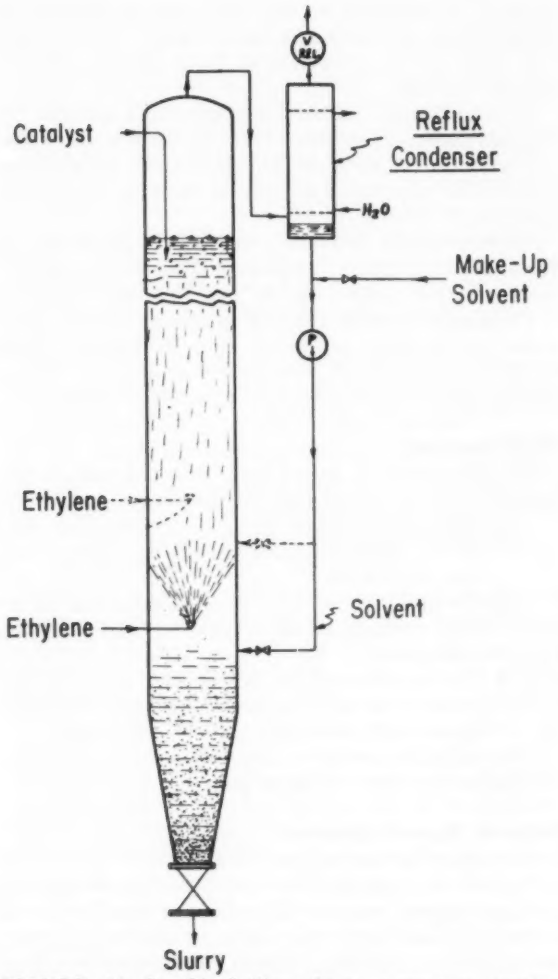

FIGURE 14—In this boiling-solvent, tower-type reactor, catalyst flows downward countercurrent to ethylene rising upward in a boiling solvent.

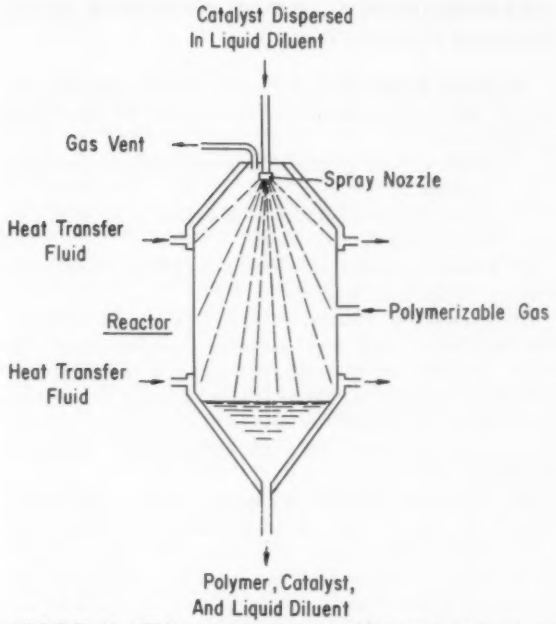

FIGURE 15—This spray reactor combines intimate contact of olefin and catalyst with high concentration of polymer relative to liquid diluent and reduction of fouling of heat transfer surfaces by polymer.

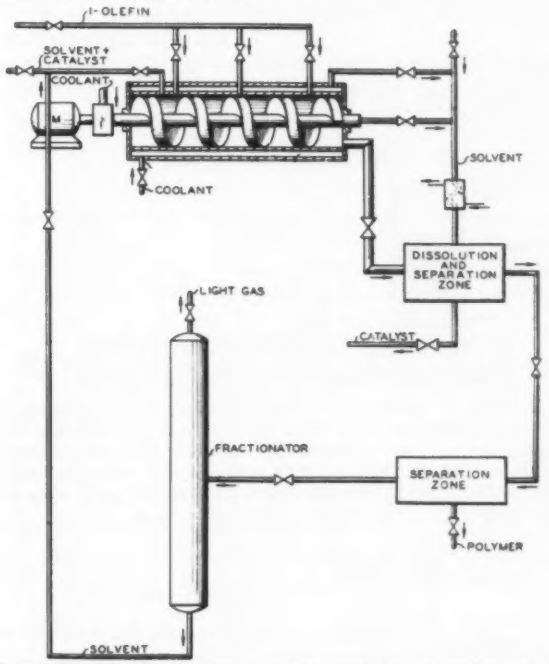

FIGURE 16—Screw-type reactors permits operation with high polymer concentrations (10-50 percent) in the effluent, whereas plugging and poor heat transfer would result at polymer concentrations above 5 percent in a conventional reactor.

the polymer in the lower portion of the tower. Productivities of 1.5 pounds of polyethylene per hour per gallon of reactor volume are claimed for this design—five times that attainable in a conventional stirred vessel. Release of high pressure ethylene directly into the reaction zone through special nozzles is claimed to give very fine bubbles from 0.01 to 0.5 mm. in diameter and averaging less than 0.1 mm. in diameter. Such a fine degree of dispersion reduces the necessary height of the reactor, it is claimed.[284]

10. Droplet-phase column-type reactors. One of a series of Shell patents[62] covers a non-agitated tower type reactor in which the olefin moves up through the liquid aqueous reaction medium by virtue of the difference in density between the droplets and the medium. The reasons for avoidance of conventional stirrers are similar to those set forth in the patents cited above.[9] Production rates of 75 to 300 grams of polymer per liter of aqueous phase per hour are claimed in operation at 15 to 70° C and under pressure adequate to insure liquid state conditions. Operations with an emulsion in place of the aqueous phase is also covered[84] and is claimed to give higher molecular weight polymer as a consequence of higher monomer concentration. Addition of a liquid, non-polymerizable substance, such as pentane, to the system is also claimed[87]; variation in the proportion of pentane present permits control of the molecular weight of the polymer produced. Control of reactor pressure fluctuations in such a system[105] and internal mixing circuits[122] have also been described.

11. Spray reactor.[237] See Figure 15. It is claimed that such a device combines intimate contact of olefin and catalyst with

a. High concentration of polymer relative to liquid diluent
b. Lowering or elimination of fouling of heat transfer surfaces by polymer.

12. Tubular converters where the catalyst constitutes a lining on the tube walls.[209]

13. Screw-type reactor.[212] This type of reactor permits operation with high polymer concentrations (10 to 50 percent) in the effluent, whereas plugging and poor heat transfer would result at polymer concentrations above 5 percent in conventional reactor due to the viscous nature of the more concentrated solutions. See Figure 16.

14. A polymer-catalyst disengager reactor is shown in Figure 17. Here, reaction takes place in a fixed bed but polymer chains grow downward and are oriented by the flow of liquid reaction medium. Then they are cleaved and conveyed away from the catalyst without ever being severed from the catalyst and (most important) without carrying any of the catalyst along with them.[296] A variation of this same concept involves a catalyst bed maintained in the periphery of a basket centrifuge where centrifugal force orients polymer growth outward.

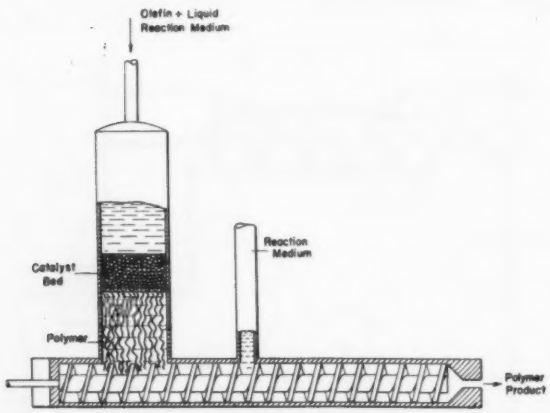

FIGURE 17—Reaction in this polymer-catalyst disengager reactor takes place in a fixed bed but polymer chains grow downward and are oriented by the flow of liquid reaction medium. Polymer chains are conveyed away from the catalyst without being severed from the catalyst and without carrying any of the catalyst along with them.

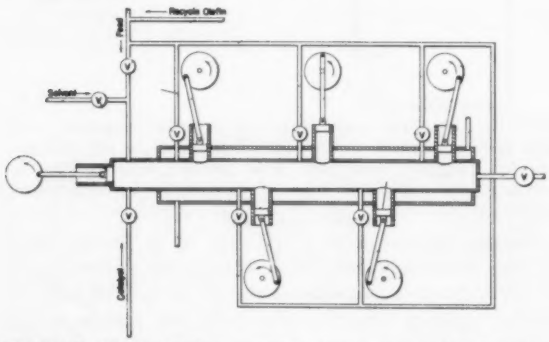

FIGURE 18—Pulsating reactors are claimed to give improved ratio of isotactic to attactic polymer due to the turbulence imparted to the reaction medium.

15. A pulsating reactor incorporating a number of opposed pistons in cylinders entering the reactor chamber has been patented.[314] The turbulence imparted is claimed to improve the ratio of isotactic to atactic polymer. See Figure 18.

16. Mechanical activation reactors[225] in which a metal is cut to that a fresh metallic surface is exposed to the catalyst components or to the reaction mixture.

17. Reactor-settlers in which upflowing catalyst particles are retained within an agitated reactor, from which a catalyst-free polymer-solvent mixture leaves continuously from a disengager space at the top.[71]

Heat Removal

Suitable measures to achieve rapid removal of the heat of reaction in ethylene polymerization are:[1]

1. The use of diluents for the ethylene (e.g., the use of industrial gases containing olefins such as cracked gases)
2. The use of a reaction vessel constructed of, or lined with, a metal or alloy of high thermal conductivity
3. The initiation of the reaction by means of an internal heating element of small heat capacity spaced within a cold-walled reaction vessel
4. Efficient stirring of the system during reaction
5. Reflux operation under pressure.

Polymer Deposit Removal

A category of operating problem which may seem to be more in a maintenance than a process category is polymer deposit removal. However, polymer removal is so closely associated with proper equipment performance (catalyst activity, agitation, heat transfer) that it will be discussed briefly here.

Branched chain paraffin hydrocarbons having boiling ranges of 350° to 600° F and having nine or more carbon atoms per molecule constitute one class of preferred solvents.[120] Heavy alkylates boiling between 425° and 500° F are particularly suitable. Such a solvent is used at a treating temperature of 300° to 400° F which is above the melting point of the polymer to be removed.

Solid polypropylene deposits can be removed from reactor systems by first oxidizing with air at 338° to 464° F for a time sufficient to combine 0.2 to 4.0 weight percent of oxygen with the polypropylene. The oxidized polymer is then contacted with a hot organic solvent (aldehyde, ketone, alcohol, ether or hydrocarbon) boiling above 200° F to effect removal of the polymer.[179]

Polymer removal may be effected during the process itself, rather than by subsequent solvent treatments, by a patented anti-fouling procedure.[242] This involves superheating of the polymerization reactor wall to a temperature in excess of 200° F for a suitable period—say by heating the reactor wall to 200° to 400° F for 5 to 10 minutes. The reactor is then allowed to cool again. The cleaning rate may be enhanced by a rapid but controlled reduction in reactor pressure when the reactor wall is at the elevated temperature level.

Catalysts

IT HAS BEEN pointed out[35] that olefin polymerization is not new. Thus, ethylene polymerization has been accomplished by heat, pressure, ultraviolet light, silent electric discharge, cathode rays and by a large number of catalysts, as well as by combinations of these techniques. In general, however, the first five (non-catalytic) methods cited above tend to produce liquid to oily materials of relatively low molecular weight. On the other hand, the use of catalysts yields products from liquids through greases and waxes to hard, tough plastics.

Beyond that, one might cite the following sequence of thoughts in support of this review:

1. There are no elegant laws of catalysis
2. There are, indeed, almost no laws of catalysis
3. There are, however, a lot of empirical facts
4. Patents, in the case of polyolefin polymer catalysis, are the best available source of such facts
5. This is a survey of those patents.

There are four essential steps in the formation of polyolefin chains: initiation, propagation, chain transfer, and termination. Most of the catalysts involved here become part of the polymer and actually initiate the chain reaction. This is in distinction to the classical concept of a catalyst which is a material which "influences" the course of a reaction but remains unchanged itself. Further, many of these catalysts direct and influence the propagation reaction to produce regularly-oriented, stereospecific polymers.

Catalysts may possess one or more of a number of drawbacks. Among these are:

1. Contamination of the olefin polymer with an inorganic residue which may impair its electrical properties and heat stability
2. Promotion of cross-linking giving a polymer of limited solubility and melt extrudability
3. Production of polymers possessing a low tensile strength.
4. Isomerization of 1-olefins to 2-olefins.

The essence of all the "low-pressure" processes for the production of linear polyolefins is the control of the polymerization reaction by immobilizing, complexing and orienting each individual monomer molecule before it is introduced into the chain and chemically attached to its predecessor. It has been thought that the small, non-polar and highly volatile monomers such as ethylene, propylene, and 1-butene require a very strong complexing capacity which can only be contributed by an active catalytic center on a solid surface. Such solid surfaces exist, of course, not only in the obviously solid Phillips and Indiana catalysts but also in the precipitated phase in Ziegler (and Alfin) catalysts. Recent work, however, has suggested that even soluble complexes of monomers with the counterions in ionic polymerization can put that monomer which is supposed to become the next member of the growing chain into such a position that it will be chemically incorporated into the growing polymer molecule under clearly restricted steric conditions. The oriented polymer chain is reeled off the active catalyst surface into the polymerization medium as it grows.

Ionic catalysts function by dissociation of a catalyst particle into a positive and a negative ion in an organic environment. Thus, when BF_3 is used as a catalyst, it forms a hydrate BF_3OH_2 which dissociates into a cation (H^+) and a negative complex counterion (BF_3OH^-). The chain grows on the cation and this particular process is known as cationic polymerization. When an alkyllithium compound is used as a catalyst, it dissociates into a cation (Li^+) and an anion (R^-); in this case the cation is the counterion and the chain grows on the anion and this process is now known as anionic polymerization.

Table 10, adapted from Natta,[349] presents a comparison of some of the essential features of anionic and cationic polymerization processes.

METALLIC CATALYSTS

A general combination that seems to be effective in converting olefins to high polymers—and one that seems to embody the fundamentals of the Natta, Ziegler, and Indiana catalysts—is the combination of a polyvalent metallic ion which is capable of existing in various oxidation states—together with a mild reducing agent (such as an aluminum alkyl or an alkali or alkaline earth metal, hydride or alkyl). In the Ziegler and Natta catalysts, there is a titanium salt in the presence of an aluminum alkyl; in the Indiana catalyst there may be a molybdenum salt in the presence of an alkali hydride. The mild reducing agent places the complex heavy metal ion in an intermediate valence state in which it becomes the active catalyst. Admittedly, this explanation is oversimplified, but it offers one guide to the understanding of these complex metal catalysts.

TABLE 10—Comparison of Cationic and Anionic Polymerization Processes[349]

	Cationic	Anionic
Catalyst	Salts of carbonium ions or acids	Salts of carbanions or metal hydrides
Chain starters	H^+ - $R'R''$ C^+	H^- - CH^-_2 - Ar^-
Other ions	BF_3OH^- $AlBr_4^-$ (Anions)	$TiAlX_n^+$ AlX_2^+ (Cations)
Principal catalysts	Salts of strong acids with weak bases, electrophilic-substances, compounds of groups II - IV and higher group metals in their highest oxidation state ($AlCl_3$, $TiCl_4$).	Salts of strong bases, nucleophilic materials, Compounds of the lowest oxidation states of group IV - VIII metals ($TiCl_2$, VCl_2, etc.)
Co-Catalysts	Substances giving rise to protons or carbonium ions: HX, RX, HCl, H_2O, etc.	Substances giving rise to hydride ions or carbanions: MH, MR
Scale of increasing reactivity of olefins	CH_2 = CH_2 RCH = CH_2 $RR'C$ = OH_2	$RR'C$ = CH_2 RCH = CH_2 CH_2 = CH_2
Inhibitors	Electron donors: bases, amines, alcohols	Electron acceptors: acids, water, aliphatic halides
Solvents	Hydrocarbons	Hydrocarbons, aromatic halides
Chain termination	Proton transfer to catalyst or monomer	Hydride anion transfer to catalyst or monomer
Copolymerization of polymer and its own monomer	Frequent	Rare with ethylene; none with higher olefins
Structure of polymer formed	Irregular; long branched chains; some cyclization	Regular; absence of branches or rings

One of the early metallic catalysts[4] was a combination of a hydrogenating catalyst (such as nickel on a kieselguhr support) with an alkali metal hydride or alkyl (preferably a lithium alkyl). A patent was granted on Aug. 20, 1940 covering the use of this combination at 50°-100° C and 400 to 2,000 psi in the presence of an inert organic solvent during a reaction period of several hours for the production of wax-like polymers of ethylene.

Figure 19 shows the periodic table of the elements showing those elements used in polyolefin catalysts described in the patent literature. The designation of the elements is complicated by the fact that what most periodic tables now refer to as Group VIb (Cr, Mo, W, and U) is referred to as Group VIa in some patents[11] based on another form of the periodic table.

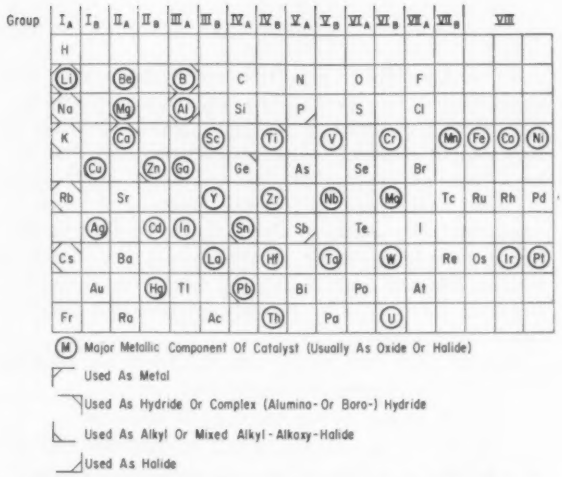
Group
IA IB IIA IIB IIIA IIIB IVA IVB VA VB VIA VIB VIIA VIIB VIII
H
Li Be B C N O F
Na Mg Al Si P S Cl
K Ca Sc Ti V Cr Mn Fe Co Ni
Cu Zn Ga Ge As Se Br
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd
Ag Cd In Sn Sb Te I
Cs Ba La Hf Ta W Re Os Ir Pt
Au Hg Tl Pb Bi Po At
Fr Ra Ac Th Pa U
(M) Major Metallic Component Of Catalyst (Usually As Oxide Or Halide)
Used As Metal
Used As Hydride Or Complex (Alumino-Or Boro-) Hydride
Used As Alkyl Or Mixed Alkyl-Alkoxy-Halide
Used As Halide

FIGURE 19—These elements have been described in the patent literature as being used in polyolefin catalysts.

Processes Using Non-Metallic Catalysts

THE PROCESSES described in this section of this survey are primarily free-radical polymerization processes. Since the intent here is to emphasize the materials and equipment used and not to try to pre-judge the operative reaction mechanisms, we will not use the "free radical catalyzed" category here.

Processes using peroxy or azo catalysts depend in most cases on thermal decomposition of the catalyst to free radicals which initiate the polymerization reaction. Since such temperatures are well above the critical temperature of ethylene, very high pressures are required to maintain the ethylene in a pseudo-liquid condition to insure that the free radicals will collide with an ethylene molecule during their relatively short life, and to insure that the resulting activated ethylene molecule will collide with another molecule of ethylene to form an activated dimer and so on until a polymer of the desired high molecular weight is produced. There is thus a tendency to lump these processes together as high pressure processes but this is not a good designation because, in the presence of sufficiently active peroxides, operations may be carried out even at atmospheric pressure.[211]

Another point to be made is that these processes have been confined to ethylene polymerization. In fact the statement has been made[240] that "polypropylene in solid form cannot be produced by the usual high pressure polymerization processes." There have, however, been reports that development work is being carried out on a high-pressure polypropylene process. The problem is that the methyl group enters into the reaction giving a cross-linked polymer which is difficult to process. The advantage is that existing high-pressure polyethylene plant capacity could be converted to polypropylene manufacture directly if a high-pressure polypropylene process could be made practical.

Recently it has been shown[340A] that some of these free radical catalysts are capable of producing stereoregular polymers. The free radical chain ends can exert a regulating influence on the entry of the next monomer molecule if the substituents are large and polar and if other conditions such as solvent and temperature, favor sufficiently the prevalence of one steric state over the other.

OXYGEN AND PEROXIDES AS CATALYSTS

The first ethylene polymerization process yielding a resinous product was carried out at very high pressures using small amounts of molecular oxygen as a catalyst. Subsequently, a variety of processes using oxygen, organic peroxides, and inorganic per-compounds as catalysts have been developed for conduct in vapor-phase, aqueous phase, and solution-phase processes.

Catalyst efficiencies in peroxide-initiated processes have been quoted as 30-200 lb. polymer/lb. catalyst for a di-tertiary-butyl peroxide catalyst[51] and as 100 to 4,500 lb. polymer/lb. catalyst for peroxydicarbonate ester catalysts.[69] The 4,500 figure is quite high for olefin polymers and compares with figures for diene polymerization.

In the water-peroxide catalyzed polymerization of ethylene, the higher the oxygen content of the ethylene fed, the lower the rate of reaction and yield of polymer, the lower the intrinsic viscosity of the polymer obtained, and the higher the catalyst requirements of the reaction.[19] Thus, it is advantageous to de-oxygenate the system before pressuring with ethylene and to use ethylene containing less than 400 ppm of oxygen, generally less than 50 ppm and preferably less than 5 ppm of oxygen.

I.C.I. Process

The I.C.I. process (Figure 20) has been described in the periodical literature by Richards,[353] by Perrin,[350] and by Thomasson, McKetta and Ponder.[359] Variations include:

1. A technique[1] in which ethylene alone (containing no oxygen) is heated to 390°F and fed to a stainless steel reactor where it is held for a reaction period of about four hours. The heat of reaction is removed con-

tinuously and the product is recovered by releasing the pressure at reaction temperature. The molecular weight of the product is little affected by variations in operating temperature but is materially affected by variations in operating pressure:

Press., Atm.	Mole wt.
500	2000
1500	6000-12,000
3000	12,000-24,000

Conversion of ethylene to polymer in this process variation may be as high as 90 percent.

2. A bulk technique[2] in which ethylene at 1,500 atm. containing 600 ppm (0.06 percent) of oxygen is heated to 375°F and fed to a stainless steel reactor which operates isothermally. A conversion of 25 percent is typical and reaction time is only a few seconds. Reactor effluent goes to a separator and unconverted ethylene (now free from oxygen, which was consumed in the reaction) is recycled to the charge gas compressor. Liquid polyethylene resin from the separator is water-white and very viscous, having a molecular weight from 6,000 to 12,000. It is chilled quickly, then chopped and stored in bins prior to bagging and shipping.

3. A technique using reaction conditions similar to the two previous cases but specifically applied to interpolymers with other polymerizable organic compounds, including other olefins.[3]

In the I. C. I. process, according to Aggarwal and Sweeting,[3,18] the incoming ethylene stream must be free of impurities (normally, 99.5 percent ethylene is required). The absence of acetylene is particularly important. The oxygen content is usually controlled by reducing the oxygen content of the incoming ethylene stream to 0.001 percent and then adding the amount of oxygen required as a polymerization catalyst.

Higher yields of higher molecular weight polymers can be obtained at lower operating temperatures and pressures it is claimed[14] when perhaps 0.2 percent of a water soluble salt of an oxy acid of sulfur with reducing properties is added to the aqueous solution. Examples of such salts include sodium hydrosulfite (preferred), sodium bisulfite, sodium hydrosulfate, and alkali metal persulfates.

A modified I. C. I. process producing polymers having a density greater than 0.925 is carried out at temperatures below 150°C (say 55 to 110°C) and pressures above 500 atmospheres in the presence of a free-radical producing catalyst and of a chain-transfer agent such as hydrogen, carbon tetrachloride, or chloroform. Peroxydicarbonate esters, alkyl or aryl hyponitrites, or alpha-substituted acyl peroxides are suitable catalysts.[14,16] From 5 to 100 ppm of catalyst per part of ethylene are used.

Du Pont Process

A high pressure process which is in some respects a solvent modification of the original I.C.I. process is the Du Pont process first described[10] by Greenewalt.

In this process, as shown in Figure 21, ethylene is first compressed to a pressure between 20 and 150 atmospheres, then cooled to a temperature between—35° and + 5° F whereby it is liquefied. Benzene is then introduced at the rate of 0.05 to 2.0 parts per part of ethylene. The pressure on this liquid mixture is then raised to between 800 and 1,500 atmospheres and the mixture is preheated to 50°-400°C before introduction

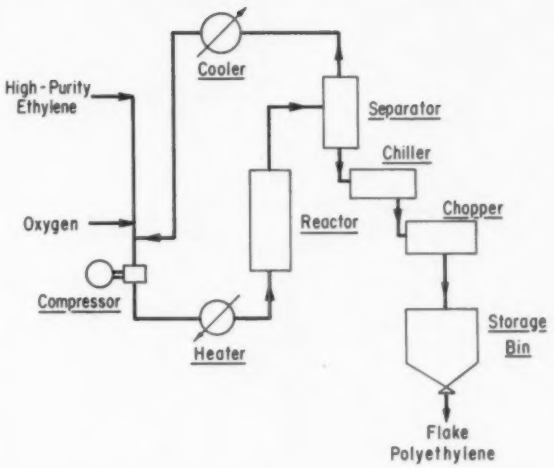

FIGURE 20—Flow diagram for the I. C. I. polyethylene process.

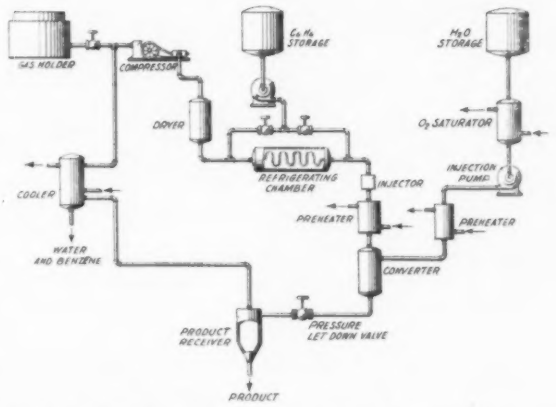

FIGURE 21—Flow diagram of the Du Pont high pressure polyethylene process.

to the reactor. Simultaneously, 0.1 to 10.0 parts of water per part of ethylene are injected into the reactor. The total oxygen present in the reaction zone (as elemental oxygen or peroxides equivalent thereto) is 20 to 2,000 ppm based on the ethylene present.

The Greenewalt patent was far-seeing in specifying that it covered "any polymerizable aliphatic monoolefinic hydrocarbon," and goes on to name propylene as one other monomer beside ethylene which can be converted to a polymer by this process. One must remember that this was in an era when even polyethylene was newsworthy and resinous polypropylene was essentially unknown.

A variation of the Greenewalt patent involves recovery of recycled ethylene at two pressure levels—one a high pressure recycle stream and the second a low pressure recycle stream.[18]

Alkaline agents may be added to the water such that its pH is above 7 and is preferably in the range of 11 to 14.[12] Improved polymer properties are claimed for such a process.

On the other hand, a shorter induction period and higher reaction velocity are claimed[16] when the reaction is conducted in the presence of water whose pH is

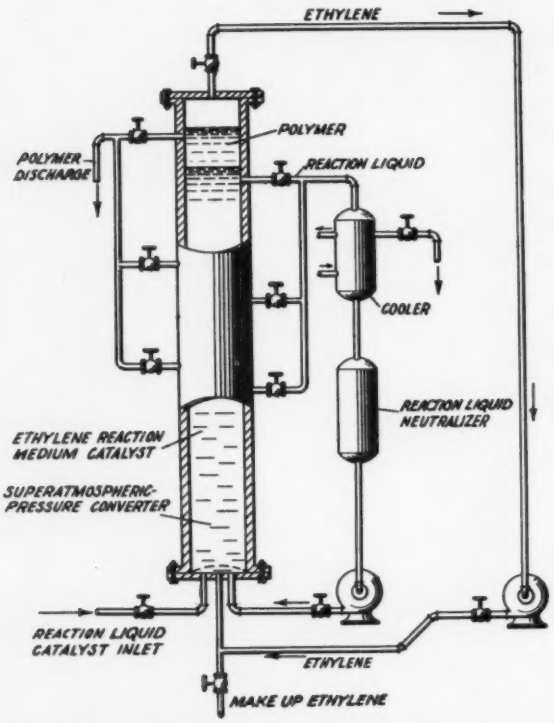

FIGURE 22—Reactor for the Du Pont process is a thick wall converter into which water containing a peroxide catalyst plus benzene or chlorobenzene are introduced.

maintained in the range of 1 to 6 and preferably from 2.0 to 4.0. A benzoyl peroxide catalyst was employed in this process variation.

Water alone may be used[17] as the operating medium to give polymers of higher intrinsic viscosity than are otherwise obtained and to avoid the need for solvent recovery which is otherwise economically necessary. When water alone is used, the absence of a dispersing agent is desirable. Such an omission increases the intrinsic viscosity of the polymer formed and avoids the necessity of removing the dispersing agent from the polymer—a step which is sometimes quite difficult.

However, improved polymer physical properties are obtained when the polymer is prepared in the presence of benzene and/or monochlorobenzene,[22] as well as water, as described in the Greenewalt patent cited above.

A reactor for the conduct of the Du Pont process is shown in Figure 22.[24] It provides a thick wall convertor into which water containing a peroxide catalyst plus benzene or chlorobenzene are introduced. A valve is used to regulate the height of liquid in the convertor, and thus the contact time. Unreacted ethylene is removed and is recycled. Reaction liquid (water plus aromatic) is removed, passed through a cooler and a neutralizer where ammonia may be added to neutralize any acids produced. The liquid is then returned by a pump to the reactor.

Another design patented by Du Pont is a mixer reactor which features a high degree of end-over-end mixing. See Figure 23.

Polymer recovery from high pressure processes may be achieved by first condensing out the polymer at reaction temperature and pressure (say 1,000 atm. and 200°C) and then effecting a further separation at lower pressure and/or lowered temperature to produce a second polymer fraction having different properties from that condensed out under reaction conditions.[11]

The polyethylene may be recovered as an emulsion by introducing a dispersing agent to the polymer issuing from the reactor and before the pressure let-down valve. The polymer plus the dispersing agent are then blown down into a stirred product receiver. An aqueous condensate is circulated from this receiver through a cooler; a portion of this circulating stream is bled off as the product emulsion.[29] The polymerization leading to the production of such an emulsion can be conducted in the presence of peroxy or azo catalysts.

Two-stage recovery of the product polymer is covered in one patent[63] which specifies first stage separation of water as a lower layer and polymer plus ethylene as an upper layer. This is followed by a second stage in which the organic layer from the first stage is separated into unreacted ethylene, which is recycled, and polymer free of water and ethylene.

Carbide Process

Ethylene, together with a molecular oxygen catalyst is compressed to 2,000 atmospheres and fed to a heater having a 3/16-inch inside diameter and a length of 60 feet at a rate of 29.3 pounds per hour. In an average time of 45 seconds at 175°C, 21.7 percent of the ethylene fed was converted to polymer.[136]

Ethylene may be admixed with from 0.2 to 3.0 percent by volume of a 1-olefin such as propylene or butene to produce a copolymer by a similar process.[144] The mixture is compressed to 20,000 to 40,000 psi and polymerized at a temperature of 160° to 350°C. At temperatures in the lower part of that range, namely 160° to 220°C, from 20 to 200 ppm by volume of oxygen can be used; at higher temperatures, oxygen in the range of 20 to 50 ppm will suffice. The reaction is

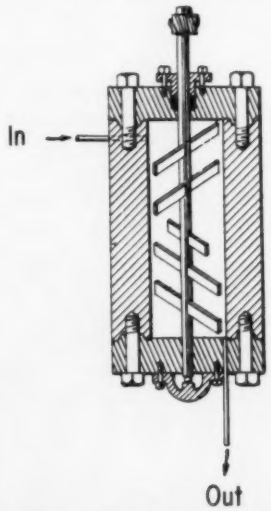

FIGURE 23—Another feature of the Du Pont process is a mixer reactor which gives a high degree of end-over-end mixing.

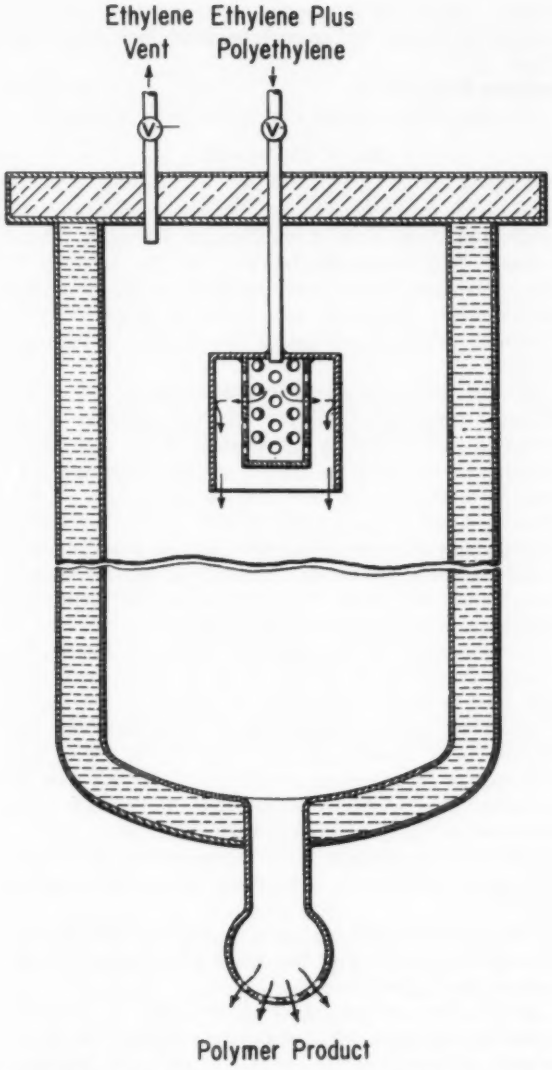

FIGURE 24—Polyolefins may be continuously recovered in extruded form by using the temperature and pressure of the gas leaving the reactor for the extrusion.

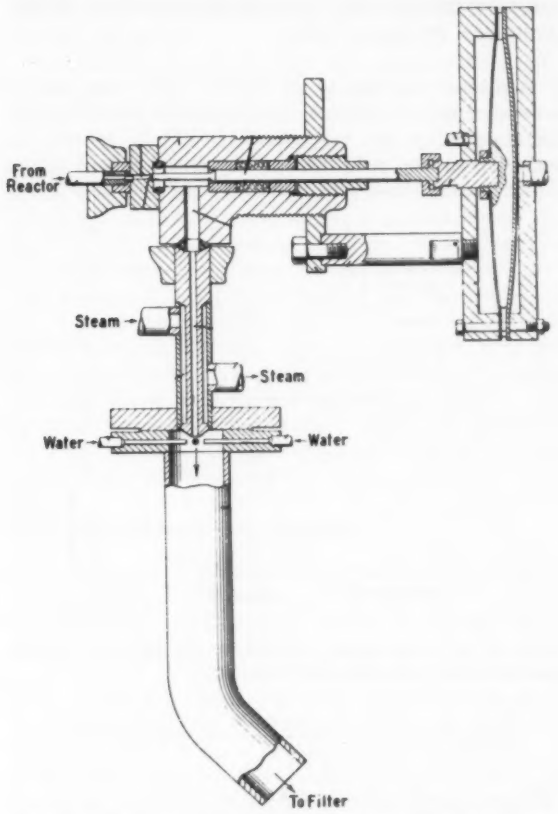

FIGURE 25—Powdered polymers or copolymers of ethylene may be recovered directly from a reactor effluent by injecting a high velocity jet of atomized molten polymer into a quenching fluid.

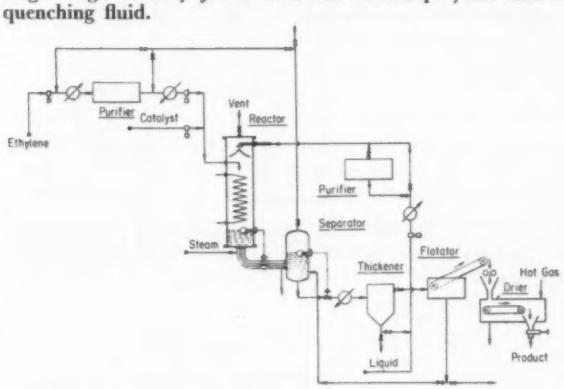

FIGURE 26—Flow diagram of the Indiana peroxide-catalyzed vapor-phase process for polyethylene.

preferably carried out in the absence of water or inert solvents. The contact time is as little as 20 to 60 seconds in the instance of long tubular type reactors and is a minimum of 3 to 5 minutes when using autoclave type reactors.

Thus, no conspicuous operating differences can be found in the patents between the I.C.I. and Carbide processes described here. Carbide, the largest single U.S. polyethylene producer has most of its plant investment in this type of high pressure process.

The continuous recovery of polyolefins in extruded form may be accomplished by utilizing the temperature and pressure of the gas leaving the reactor for effecting the extrusion.[26] In Figure 24, a collection vessel is surrounded by a heating jacket. A pipe connects with the high pressure reactor through an expansion valve; a larger perforated pipe with a closed end is attached to the end of that pipe and is surrounded by a shield. Another pressure release valve and the associated pipe are used to control the internal pressure in the collection vessel and to provide a discharge port for the unreacted ethylene gas. A neck at the bottom of the vessel has a number of small holes and these constitute extrusion nozzles for the resin.

In operation, polymer plus unreacted ethylene pass continuously or intermittently into the vessel. The mixture is ejected through the perforated pipe against the shield. The fluid polymer drains from the shield into a pool at the bottom of the vessel. At 500 psi and 250°C, the liquid resin extrudes from the nozzles and cools in the air to form filaments resembling spaghetti.

Powdered polymers or copolymers of ethylene may be recovered directly from a reactor effluent by injecting a high velocity jet (in excess of 100 ft./second) of atomized molten polymer into a quenching fluid stream which rapidly cools and freezes the polymer into a fine powder which can be readily separated from the unreacted monomer and quenching fluid and dried. See Figure 25.[136]

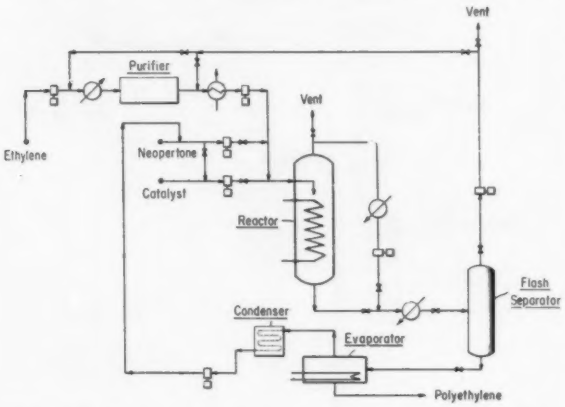

FIGURE 27—This is the solvent-type version of the Indiana peroxide-catalyzed polyethylene process.

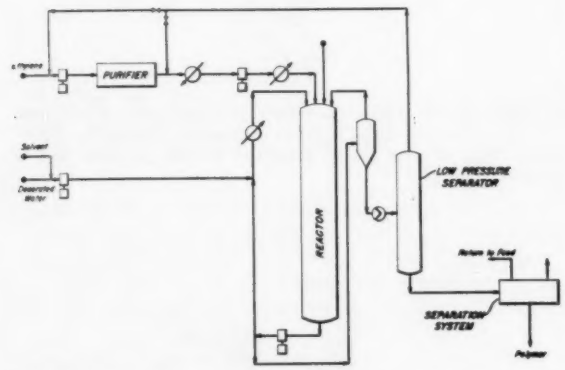

FIGURE 28—In this continuous organic phase version of the Indiana process polymer is produced as a slurry in the aqueous solution.

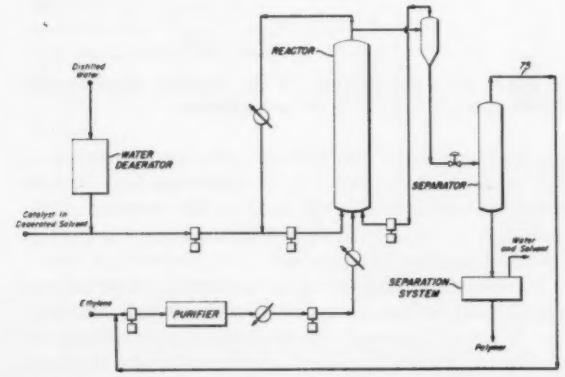

FIGURE 29—In the Indiana continuous aqueous phase process an ethylene phase is dispersed discontinuously throughout an aqueous phase.

Indiana Process

The use of compounds having the general formula

$$R_1O\text{-}\overset{\overset{O}{\|}}{C}\text{-}O\text{-}O\text{-}\overset{\overset{O}{\|}}{C}\text{-}OR_2$$

(and variously designated as diformate peroxides, dioxyformates, and peroxydicarbonates) in the polymerization of ethylene have been described by the Standard Oil Company (Indiana) in a series of patents.[39, 40, 41] Di-t-butyl peroxydicarbonate is specifically cited in one patent.[99]

The process is conducted at a temperature below the softening temperature of the ethylene polymer being produced and preferably between about 35° and 65°C. Pressures from 4,000 to 10,000 psi are employed and from 0.01 percent to 10.0 percent by weight of the peroxide based on the weight of olefin to be polymerized is used. Depending on the other reaction variables and on the nature of the product desired, the polymerization period may vary from 1 to 100 hours, but ordinarily periods of 1 to 5 hours are satisfactory.

In one version of the process,[39] shown in Figure 26, a vertical cylindrical reactor is used whose walls are kept wet by water containing a surface active agent in order to prevent accumulation of polymer in the reaction zone. From 0.001 to 2 or 3 percent of the surfactant is incorporated in the water. In this type of operation, the polymer issues from the reactor as a dispersion or slurry of solid polymer particles.

The aqueous solution may also serve the additional purpose of removing heat from the polymerization zone.[40]

Non-aqueous media such as a neopentane solvent may be employed also.[126] The flow scheme for such a process is shown in Figure 27.

In another version (not illustrated), a jacketed reactor containing a spiral scraper, provided with suitable seals, may be used for removal of the solid polymers formed.[41] In this last mentioned version, it is emphasized that no solvent is necessary for the practice of the peroxydicarbonate-catalyzed vapor-phase polymerization of ethylene.

Still another version of the Indiana peroxide process has the ethylene present in dense gaseous phase in the presence of an aqueous phase containing 10 to 25 percent of methanol or tertiary butanol.[69] This aqueous phase constitutes 25 to 90 percent of the total reaction mixture. Reaction conditions are 30° to 100°C and 4,000 to 20,000 psi in the presence of 0.001 to 1.0 weight percent of the peroxydicarbonate catalyst based on the ethylene. Constant agitation is necessary and is usually achieved by a recycle of the reactor contents through an external pump loop at the rate of 0.2 to 2.0 reactor volumes per minute depending on the size of the reactor. The polymer is produced as a slurry in the aqueous solution; not more than 30 percent and preferably not more than 15 percent by weight of polyethylene is allowed to accumulate in the slurry to insure ready flow from the reactor. The polymer is separated by flash evaporation of ethylene, followed by filtration, washing, and drying. In one variation of this process

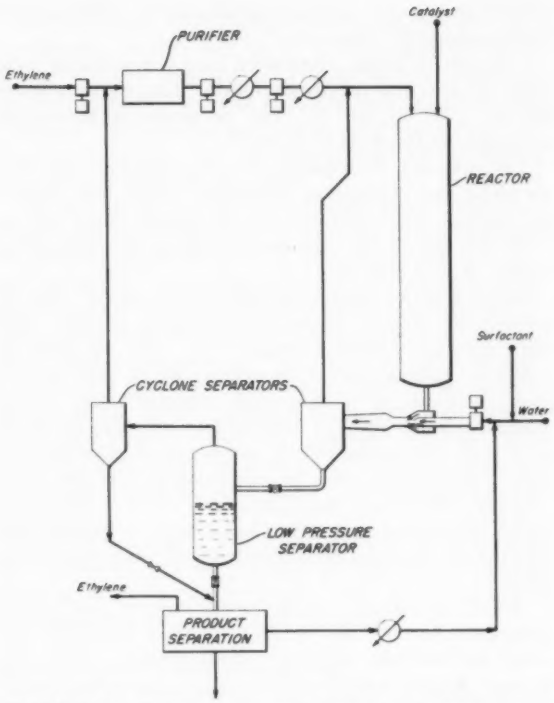

FIGURE 30—Polymer recovery from the Indiana process uses a water aspirator to withdraw the polymer stream from the reactor.

(Figure 28), the ethylene/tertiary butyl alcohol phase is the continuous phase in which the aqueous solution phase is dispersed or suspended. In another (Figure 29), an ethylene phase is dispersed discontinuously throughout an aqueous phase. The same equipment configuration as used for the latter process may be used when the aqueous phase contains a surfactant[98] in a process somewhat similar to vapor phase process which uses an aqueous surfactant-containing film on the reactor walls.[39]

A very similar technique has been described by Olin Mathieson[115] involving ethylene polymerization at 40°-55°C and 4,000-6,000 psi in the presence of a diisopropyl peroxydicarbonate catalyst in an aqueous methanol reaction medium which may contain a non-ionic emulsifying agent.

The use of aqueous films on the reactor walls and of surfactants or other materials in the reaction zone to prevent polymer buildup on the reactor walls may be avoided by using a dense ethylene phase polymerization system in which part of the ethylene is polymerized but a sufficient quantity is left unpolymerized to serve as a carrier for continuously removing polymer from the reactor.[96] The effluent stream from the reactor contains at least 0.5 percent polymer but not more than 5.0 percent polymer. This product stream can then be withdrawn from the reactor by use of a water aspirator as shown in Figure 30. The water preferentially wets the polymer and produces a dispersion of polymer in water. The polymer is centrifuged out and the dense phase ethylene returned to the reactor under the hydraulic from the aspirator jet. A surfactant is advantageously incorporated in the water jet to the aspirator.

Other Processes Using Oxygen

Operation at relatively low superatmospheric pressures is claimed for a process using an aromatic or a chlorinated aliphatic hydrocarbon solvent at 55° to 180°C and 100 to 300 atmospheres pressure.[5]

It has been pointed out that ethylene polymerization using an oxygen catalyst at high pressures is operated maintaining reaction conditions such that the system is almost on the verge of an explosion. By explosion is meant an extremely rapid and highly exothermic degradation, ranging in severity from discoloration of the polymer product up to essentially compete carbonization of ethylene and polymer. Under such conditions, exceedingly close control of the reaction is required. Polymer buildup in a pipe line reactor and subsequent tearing away of such deposits may cause pressure fluctuations and accompanying temperature fluctuations which may lead to carbonization reactions. The imposition of regular flow pulses at a controlled rate may be used to prevent irregular changes in pressure, temperature, and flow resulting from causes other than such regular pulses. The scheme shown in Figure 31 may be used to accomplish this end.[158] The likelihood of explosions can also be reduced by restricting the effective diameter of the initial portion of the reaction tube as

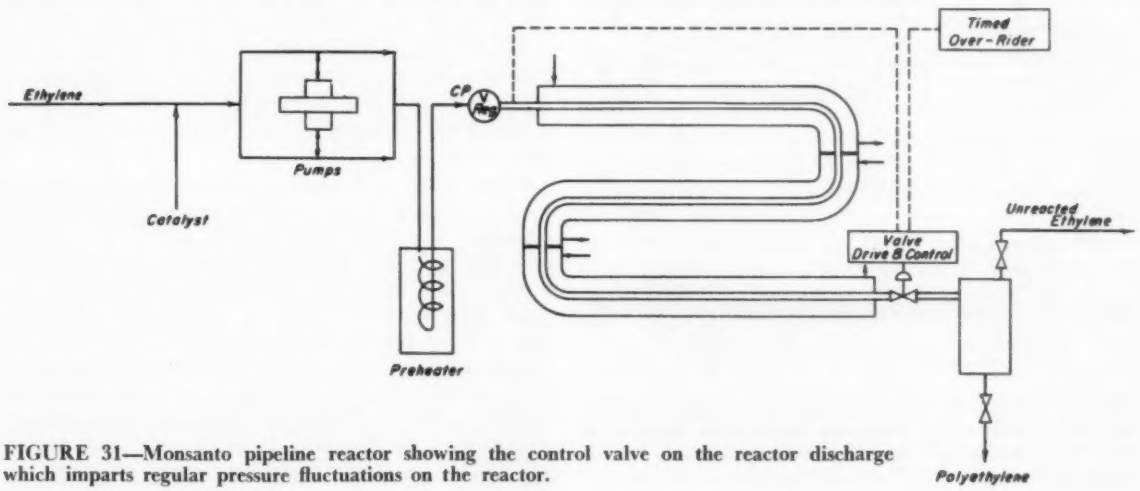

FIGURE 31—Monsanto pipeline reactor showing the control valve on the reactor discharge which imparts regular pressure fluctuations on the reactor.

compared with the rest of the tubular reactor. The preferred technique for accomplishing this is to position a retractable rod in the center of the first portion of the reactor tube. This provides a constricted annular space for the first 5 to 35 percent of the reactor which provides a highly effective means of controlling the reaction.[160] See Figure 32.

Other Processes Using Peroxides

Hydrocarbon solvents in high pressure polymerization processes ordinarily tend to give liquid products or low molecular weight polymers of low softening temperature. However, it is claimed[300] that use of saturated straight- or branched-chain aliphatic hydrocarbons having 3 to 7 carbon atoms at 80°-180°C and pressures in excess of 20,000 psi give polymers having densities of 0.93 to 0.955.

Dialkyl peroxides, ROOR,[1] are claimed[15] as superior catalysts. These materials, in which R and R^1 are simple unsubstituted alkyl groups containing not more than three carbon atoms, are prepared by reacting hydrogen peroxide in the presence of alkali with the appropriate dialkyl sulfate at 30° to 100° C. The employment of dialkyl peroxides specifically in a continuous process having a reaction zone of great length to diameter (such as 1920 to 1) at a temperature of 205° to 300° C and for a contact time of not more than 30 minutes is also described in the prior art.[25]

The use of di-tertiary butyl peroxide (as one specific dioxide) has also been patented.[45] Its use is specified at 100° to 250° C and at 10 to 1,500 atmospheres in concentrations from 0.0005 to 5.0 percent and in the presence of water alone as a reaction medium.

The use of 2, 2-bis-(tertiary butyl peroxy)butane as a catalyst for the polymerization of ethylene has been claimed by Monsanto.[64]

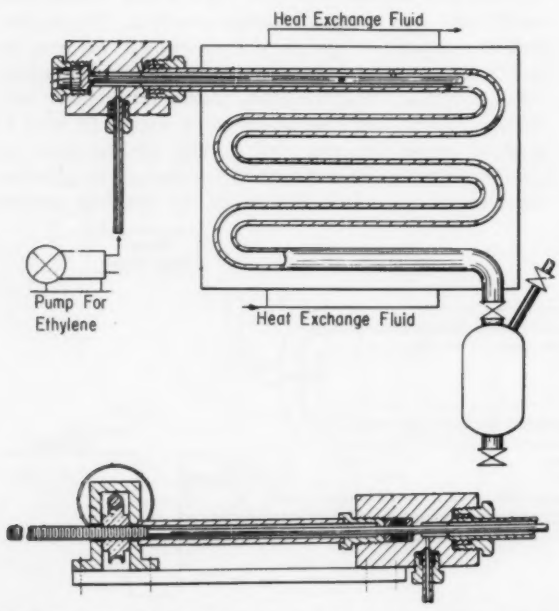

FIGURE 32—In the Monsanto pipeline reactor, explosion hazards are reduced by restricting the effective diameter of the initial portion of the reactor using control rods as shown above.

The use of alpha substituted acyl peroxides as catalysts for ethylene polymerization at temperatures below 50° C (10° to 50° C) and at pressures above 500 atmospheres has been claimed.[168]

Di-(polyenic, cyclopentenyl) peroxides may be used as olefin polymerization catalysts.[60] They are claimed to enhance polymerization in the initial stages and to limit the size of the polymer formed in the concluding stages of the reaction.

Alkyl hydroperoxides, ROOH, are claimed[23] for the production of polyethylenes of excellent solubility and melt extrusion characteristics. They may be used for ethylene polymerization in water, water plus an organic medium, or in an organic medium alone at temperatures from 100° to 400° C and ethylene pressures of 50 to 3,000 atmospheres. Amounts of catalyst from 0.0005 to 2 percent may be used based on total monomer charged. The alkyl hydroperoxides are less expensive, easier to synthesize and less hazardous to handle than the dialkyl dioxides mentioned in the preceding paragraph.

Alkali or alkaline earth metal salts of the hydroperoxides having the general formula R-OOM and more particularly, alkali or alkaline earth metal salts of aryl dialkyl hydroperoxides such as cumene hydroperoxide are useful olefin polymerization catalysts.[111] Cumene may be used as the inert diluent in a process using from 0.0001 to 12.0 percent of a cumene hydroperoxide catalyst at temperatures of 145° to 175° C and pressures of 200 to 1,000 atmospheres.

The use of tertiary alkyl percarboxylates of the general formula $\mathrm{ROOCR_1 \atop \| \atop O}$ (in which R is a tertiary butyl group and R_1 is a hydrocarbon group in which the alpha carbon atom is attached only to carbon atoms) has also been patented.[43] A typical example of a percarboxylate covered by the invention is tertiary butyl perbenzoate. From 0.0005 to 2 percent of the catalyst is employed at a reaction temperature of 70° to 250° C and under a reaction pressure of 400 to 1,000 atmospheres.

Tertiary alkyl peresters of the formula $\mathrm{RCOOC\text{-}CR_3 \atop \| \atop O}$ may be used in the presence of a controlled amount of a tertiary alkyl hydroperoxide.[249] The added hydroperoxide imparts improved transparency to the polymer over that obtained when the perester is used alone as a catalyst. Reaction conditions are 150° to 230° C, 1,000 - 2,000 atmospheres, and a reaction time of two minutes or less.

From 0.001 to 5 percent, and preferably from 0.1 to 0.2 percent of an organic polyperoxide may be employed in olefin polymerization at 120° to 250° C and 200 to 3,000 atmospheres in the presence of a benzene or a benzene-water mixture.[44] The term "organic polyperoxide" refers to compounds containing two or more peroxy linkages, - O - O -, and which are obtained by reacting, under peroxide-forming conditions, either a ketone or aldehyde, or a mixture of two ketones or of two aldehydes. Typically, such polyperoxides may be prepared from acetone and methylethylketone, or from acetone and cyclohexanone.

The use of peroxygen compound in conjunction with a polyvalent metal ion in a lower valence state is claimed for the production of high density polyethylene.[107] Polyvalent metals of numbers 22 to 29 (titanium, vanadium, chromium, manganese, iron, cobalt, nickel and copper) were cited and ferrous ions were preferred for economic and other reasons.

The use of peroxides (or possibly other substances which yield oxygen or free radicals, including titanium dioxide and tetraethyllead (in conjunction with a second compound containing a readily extractable hydrogen atom has been patented.[108] Preferred compounds in the latter category include isopropyl isobutyrate, ethyl malononitrile, isobutyronitrile, and isobutyl benzoate. It is claimed that this binary catalyst system is operable over a much wider temperature range than conventional free radical producing catalysts. Further, it is easy to handle, yields no oxygenated residues, forms no gases, and gives a polymer having good physical properties.

Peroxysilica, made by the treatment of finely divided silica with H_2O_2, is an effective polymerization catalyst which remains in the polymer producing essentially a peroxide-catalyzed, silica-filled polymer.[77]

Other Processes Using Ozonides

The use of the ozonides of cyclohexene and of diisobutylene has been suggested[83] for ethylene polymerization. Ozonides are stated to be stable compounds under the usual conditions of preparation and processing and are thus claimed to provide greater safety and convenience in handling than the peroxides. The proportions of the ozonide catalyst to be used vary with the ozone content of the catalyst. The percentage of combined ozone may vary from 1 to 30 percent and the proportion of catalyst may vary from 0.1 to 5.0 percent based on the ethylene charged.

NITROGEN COMPOUNDS AS CATALYSTS

Azo compounds, amine oxides, hydrazines, and hydrazinium compounds are among the types of compounds cited in a patent[123] for the production of linear polymers (density 0.95 - 0.97) at high pressures (5,000 to 20,000 atm.) and temperatures of 45° to 100° C.

The use of metallic salts in conjunction with nitrogen compounds has also been covered. Thus, titanous ion plus hydroxylamine is the subject of one patent[51] and vanadous ion plus a hydroxylamine salt the subject of another[67] on catalyst compositions. Still another involves the combination of an aliphatic azo compound with a tetravalent titanium salt as an olefin polymerization catalyst.[262]

Azo Compounds

A variety of different azo compounds are cited in the prior art as olefin polymerization catalysts.

Alpha,alpha'-azobis (alkanenitriles) such as alpha-alpha'-azo-bis isobutyronitrile and 1, 1'-azo-bis cyclohexanecarbonitrile can be used in amounts as low as 0.0002 and up to 5 percent at a pressure of 900 atmospheres and a temperature of 50°-100° C for 13-14 hours in ethylene polymerization.[37] Liquid phase polymerization was customarily used and light of wave lengths of 3,100 to 4,500 Angstrom units may be used to increase the rate of polymerization and permit the use of temperatures from +35° C to —20° C or even lower. These azo catalysts are claimed to have the following advantages:

1. They can be chosen to be effective at relatively high or relatively low temperatures
2. They have short induction periods
3. They are safe to handle—less sensitive to heat and impact than peroxides
4. They are less likely to induce cross linking than are peroxy catalysts
5. They are not easily poisoned
6. They yield products devoid of oxidizing catalyst residues and having improved color
7. They do not adversely affect dyestuffs or pigments incorporated during polymerization as peroxides do.

Azonitriles are claimed as useful water-soluble polymerization catalysts and specifically compounds of the general formula

$$RCH\ (COOY)CH_2C(R_1)\ (CN)N =$$
$$N(CN)\ (R_1)CH_2(COOY)\ CHR$$

where

Y is a monovalent cation

R and R_1 are C_1 to C_6 alkyl radicals.[46]

Dialkyldiguanylazoalkanes in which the alkyl groups are C_1 to C_4 are the preferred compositions in one catalyst patent.[58] The patent covers azo compounds in which both of the nitrogens are bonded to aliphatic carbon atoms, one or both of which are tertiary and bear a guanyl radical.

Aromatic diazosulfones are claimed to be effective catalysts, particularly in the presence of small amounts of a cupric salt.[54] From 0.01 to 5.0 percent of the azosulfone may be used, based on the monomer. From 0.001 to 10 percent of the cupric salt may be used, based on the diazosulfone.

Azodisulfonic acids may also be used in ethylene polymerization.[36] Postassium azodisulfonate, for example, may be used in bulk, solution, or emulsion polymerization processes at temperatures below 100° C. Best results were obtained above —10° C in water while below —10° C, liquid ammonia was the preferred reaction medium.

Azo catalysts which are useful at higher temperatures and specifically over a temperature range of 60° to 250° C are the araliphatic azo compounds of the formula $Ar\,CHR — N = N — CHR\,Ar$ where Ar is an aryl radical and R is a hydrocarbon radical of 1 to 10 carbon atoms.[47] Generally 0.1 to 3.0 percent of such a catalyst is employed based on the weight of the monomer.

Azo compounds of the type formula $R — N = N — OCOR$ such as benzene diazoacetate and of the type formula $R — N = N — OCO — (CH_2)_n COO — N = N — R$ such as bis-benzenediazosuccinate may be used in ethylene polymerization.[106] These compounds are claimed to be safer and easier to handle than peroxides and to permit the use of lower operating pressures than are necessary when peroxide catalysts are used. From 0.01 to 2.0 percent of such catalysts are used based on the olefin to be polymerized

at temperatures from 35° to 250° C and pressures from 4,000 to 10,000 psi.

The use of azo catalysts in conjunction with hydrogen in the polymerization of ethylene gives polymers having a density greater than 0.930 in high pressure operations.[173]

Amine Oxides

Amine oxides, such as trimethylamine oxide hydrate, triethylamine oxide hydrate, and dimethylaniline oxide may be used[20] in the bulk, solution, or emulsion polymerization of olefins. The preferred medium for use with amine oxide catalysts is water, which preferably contains a buffering agent to minimize changes in pH during the process. These catalysts may be used at temperatures from 20° to 400° C and at pressures above 4 atmospheres, but usually in the range of 200 to 3,000 atmospheres. They may be used in polymerization in the presence of hydrogen, do not have long induction periods, are rapid and durable. From 0.001 to 5 percent of the amine oxide, and preferably from 0.1 to 2 percent may be used based on the total monomer charged.

Hydrazines and Hydrazinium Compounds

Hydrazines and hydrazinium compounds may be employed[21] as olefin polymerization catalysts at temperatures of 20° to 400° C (but usually between 200° and 300° C) and at pressures of 150 to 3,000 atmospheres, in the presence or absence of hydrogen. They are generally employed in the presence of water which is held at a pH of 7 or less and which contains a buffering agent. The term hydrazines as used here includes hydrazine (H_2NNH_2) itself as well as organic substitution products of hydrazine in which one to four of the hydrogen atoms in the hydrazine are substituted by monovalent organic radicals, and salts of hydrazine with organic and inorganic acids. By hydrazinium compounds are meant compounds derived from hydrazine in which one or both of the nitrogen atoms in the hydrazine nucleus are pentavalent; trimethylhydrazinium iodide is such a compound.

Hydrazones, together with peroxides and cupric ion constitute a catalyst for use in aqueous systems.[59] From 0.01 to 5 percent of a hydrazone of the general formula $RNHN = CR'R''$ may be used based on the weight of monomer. Minor amounts of peroxide and very small amounts of cupric ion are used in conjunction with the hydrazone.

From 0.01 to 5.0 percent of an aromatic sulfonyl hydrazide (based on monomer) may be used together with 0.001 to 20 percent of cupric ion and 1 to 100 percent of a peroxy compound (the latter two based on the sulfonyl hydrazide).[70]

Oximes

From 0.1 to 2.0 percent of an oxime compound (based on weight of monomer) can be used to polymerize olefins.[32] Pressures from 200 to 3,000 atmospheres and temperatures of 60° to 400° C are specified. The term oxime refers to compounds containing the $>C = NOH$ group, which are sometimes also designated as isonitroso compounds. These oximes may be of either of two classes, aldoximes ($RCH = NOH$) or ketoximes ($RR'C — NOH$). They may also be described as hydroxylamine derivatives.

Azines

From 0.001 to 5 percent by weight of an azine catalyst may be used at 100° to 250° C and 200 to 300 atmospheres to polymerize ethylene, propylene, or butylene.[28] Azines are compounds having the grouping $>C = N — N = C<$ and can be prepared by reacting two moles of a ketone or an aldehyde with 1 mole of hydrazine according to the equation:

$2\ R_2CO + H_2NNH_2 \rightarrow R_2C = N — N = CR_2 + 2H_2O$

where R is hydrogen, alkyl, alkaryl or aryl. Typical examples or azines include dimethylketazine and benzalazine.

Azides

The use of from 0.05 to 0.5 parts of cyanuric triazide per 100 parts of monomer is claimed[53] to give an extremely active catalyst which produces high molecular weight polymers and which does not discolor the resultant polymer or leave any residue therein which adversely affects the aging properties of the polymer.

Azide ion, together with an agent which will oxidize the azide ion to liberate nitrogen, can be used in aqueous dispersion as a catalyst.[57] The oxidant materials employed may include permanganate, hypochlorite, periodate, bromate or ceric ions (the latter two in acid solution).

Hyponitrites

The use of ethyl or isobutyl hyponitrite as catalysts in a free radical catalyzed process for producing an ethylene polymer having a density of 0.925 to 0.950 has been patented.[167] Temperatures of 15° to 50° C and pressures of 1,000 to 2,000 atmospheres are employed in the presence of 0.01 to 5.0 percent of a chain transfer agent such as $CHCl_3$, CCl_4, or hydrogen.

Alkyl Nitrates

Alkyl nitrates having 1 to 8 carbon atoms are useful in the polymerization of ethylene.[294] Operating temperatures are at least 150° C, pressures are in excess of 2,500 psi, and from 0.001 to 1.5 percent of the alkyl nitrate is used based on ethylene fed.

HALOGEN COMPOUNDS AS CATALYSTS

Iodoso diacylates, of the general formula $R[I(OOR')_2]$, may be used in concentrations from 0.5 to 5.0 percent based on the olefin charged at temperatures from 0° to 100° C and pressures from atmospheric to as high as 1,000 atmospheres.[33]

Hypochlorites

The production of improved ethylene polymers, particularly in anhydrous media, and featuring short induction periods is claimed[27] for the use of hypochlorites and substances which yield hypochlorites on hydrolysis with dilute alkali. Such catalysts include calcium hypochlorite and sodio-N-chloro-para-toluene sulfonamide and are generally of the class known as positive halogen compounds. These materials may be used in polymerizing ethylene under oxygen-free con-

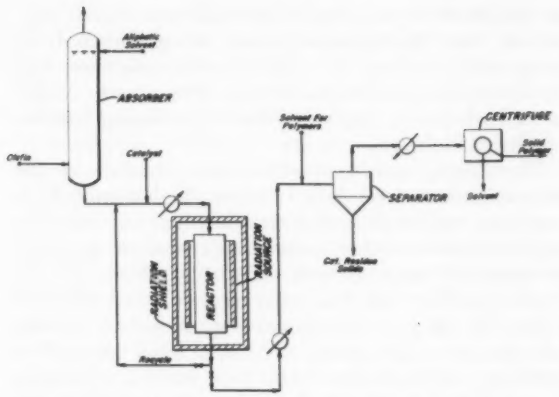

FIGURE 33—Using this process scheme, high density polyethylene can be made by exposing ethylene to gamma radiation in the presence of titanium halide.

ditions at temperatures in the range of 100° to 350° C and at pressures in the range of 100 to 1,500 atmospheres. A typical solvent for such a process is tertiary butyl alcohol. The hypochlorites are used in amounts from 0.001 to 1.0 percent based on monomers used.

IONIZING RADIATION AS A CATALYST

Gamma radiation obtained from radioactive materials, such as cobalt-60, may be used to effect polymerization of olefins. However, polymerization under the influence of gamma radiation at pressures of 5,000 psi or higher tends to be cross-linked and non-processable. However, aromatic hydrocarbons and chlorinated aromatic hydrocarbons (and particularly xylene, which is available and effective) modify the polymerization so as to permit the formation of processable polymer, it is claimed.[193]

The production of high density (0.960 or more) polyethylene can be accomplished by exposure of the ethylene to gamma radiation (in the range of 10^4 to 10^7 REP per gram of olefin) in the presence of a titanium halide.[230] See Figure 33.

Process considerations involved in the polymerization of ethylene by gamma radiation have been reviewed by Bray, Carstens, Martin and Thomas.[323] The economic aspects of the process, using spent fuel elements as the radiation source, indicate a production cost which could be competitive with conventional polyethylene processes.

USING ULTRASÓNIC WAVES

Polymerization of olefins may be carried out at 50° to 200° C and at pressures of 1 to 3,000 atmospheres in the presence of ultrasonic waves.[221] Frequencies of 250 to 375 kc/sec and a power intensity of 4 to 10 watts/sq. cm. are used. It is claimed that polymers of uniform molecular weight are obtained and that the catalyst can be used for relatively long intervals without the necessity of regeneration. Further, it is claimed that catalyst deactivated by polymer deposits can be readily cleaned up by solvent treatment in the presence of ultrasonic waves. It is still further claimed that low polymers of ethylene may be converted into suitable feed matrials for resin manufacture by the use of ultrasonic waves either prior to, or during, the polymerization process.

Processes Using Metal-Derived Catalysts

THE BIG AREA in the polyolefin field today is the field of metallic catalysts which has led to the so-called low pressure processes for the production of linear, relatively unbranched polymers. This is also the area of maximum controversy and uncertainty in the patent area.

In about 1955, the field of polyolefin resin catalysis, hitherto dominated by high-pressure, free-radical-catalyzed processes, was invaded by a trio of relatively low-pressure processes using metal-derived catalysts. These included the Ziegler process using $TiCl_4/AlR_3$ mixturs, and the Phillips and Indiana processes using solid supported oxide catalysts.

Using Metal Alkyl-Reducible Metal Halide Catalysts

The term in the above subtitle is used here to describe for the sake of convenience a wide variety of heavy metal salts plus light metal alkyl catalysts. It is used in an attempt to avoid using "Ziegler catalysts" as a generic term even though that term is quite descriptive. The problem is that Ziegler is alive and has patents in force and under license as compared to Friedel and Crafts, for example. It is hoped thus to remove any inference that Ziegler patents do or do not dominate this area. Gaylord and Mark[337] have lumped Ziegler and Alfin catalysts together with lithium and organolithium catalysts in a category called "Fluid Bed Polymerization Processes." Then they have lumped the supported oxide (Phillips and Indiana) processes together as "Fixed-Bed Polymerization Processes." Such a division appears to be wrong on at least two counts:

1. The Phillips and Indiana processes may be fixed bed operations or perhaps even more likely—slurry operations, and,

2. Fluid bed implies fluidization which is a specific physical process and which does not simply involve churning a lot of solid particles about in a fluid—a liquid in this case.

Other terms have been applied such as complex organometal catalysts and coordination catalysts, but they are not any more descriptive and do not adequately differentiate these catalysts from the promoted metal oxide catalysts. They cannot be called heterogeneous because, if anything, the Indiana and Phillips processes are more heterogeneous. Thus, it is felt that they should be called metal alkyl-reducible metal halide (or Ziegler) catalysts in contrast to preformed metal subhalide (or Natta) catalyst and supported oxide (Phillips and Indiana) catalysts.

Perhaps the metal alkyl-reducible metal halide catalysts should be attributed to Fischer who used aluminum and aluminum chloride together with $TiCl_4$ in an attempt to polymerize ethylene to lubricating oil.

This work was described in a German patent issued to Badische Anilin and Soda Fabrik in 1953, predating Ziegler's disclosures by about two years. Fischer, who obtained a minor amount of a solid white mass as a coproduct with the lubricating oil did not, however, realize that he had produced polyethylene.

The major feature of the newer metal alkyl-reducible metal halide catalysts is that high molecular weight compounds can be obtained at relatively low pressures (below 100 atmospheres) and relatively low temperatures (50° to 100° C). The polymers have molecular weights from 50,000 to 300,000 or more, softening points in the order of 130° C and above and densities of 0.94 and above.

It is interesting to note that the catalyst efficiencies, in terms of weight of polymer produced per weight of catalyst used are very low compared with comparable experience in diolefin polymerization. Thus, in making polybutadiene or polyisoprene, the value may be 1000 to 1 or even 10,000 to 1. A value of only 200 to 1 is quoted[216] for ethylene polymerization, however. Values as high as 1,000 to 1 are claimed in some olefin polymerization processes,[218] but values of 150 to 500 are cited as more typical even for that improved process and value of 20 to 100 are cited as typical for less sophisticated polyolefin processes. It must be emphasized, however, that catalyst efficiency alone is not the parameter of economic significance, but rather polymer production per unit of catalyst per unit of time.

Using Ziegler Catalysts

The discovery of the Ziegler catalyst was an outcome of a study of ethylene polymerization using aluminum alkyls alone. The dimer, trimer, tetramer, and other polymers having a molecular weight up to about 5,000 were produced. Each olefin addition step in that process is in competion with a displacement reaction which splits the growing alkyl chain away from the aluminum. In an attempt to enhance the suppression reaction and favor 1-butene formation, various metal additives were tried. Nickel worked in the desired fashion and transition metal salts were investigated to see whether they too would function as suppressors. Growth, rather than suppression, was favored and the basis for the Ziegler process was laid.

The aluminum trialkyl catalyst alone can produce solid (at least waxy solid) polymers from ethylene.[114] However, nickel, cobalt, and platinum served to activate such catalysts and to make them operable at much lower temperatures. Interestingly, the activity of these activators can be maintained at a high level by feeding 0.02 to 1.0 percent of an acetylenic hydrocarbon based on the ethylene.

The original disclosure of the Ziegler process in the periodical literature was by Ziegler, Holzkamp, Breil, and Martin.[360] It has also been described by Curphey.[328] A more recent description, summarizing recent process developments is that by Berger and Boultbee.[322]

Catalyst Composition. The Ziegler-type catalysts are the result of the reaction of two different metal compounds: one, the catalyst proper, being chosen from compounds of group IV - VIII transition elements and the other, the cocatalyst, chosen from group I - III metal hydrides or alkyls capable of producing hydride ions or carbanions.

The Ziegler catalysts which are effective in the polymerization of ethylene to linear, high-density high molecular weight polyethylene and in the stereospecific polymerization of other 1-olefins to crystalline polymers are generally heterogeneous. The solid phase may be microcrystalline and may exist as a colloidal solution. Upon the addition of titanium tetrachloride to a hexane solution of aluminum triethyl, a black precipitate is formed and a portion of this precipitate is colloidally dispersed in the solvent. Both the colloidal dispersion and the residual solid are active catalysts, but the solution is both easier to handle and a more reactive catalyst. If aluminum trioctyl is used in place of aluminum triethyl, a colored solution is obtained containing no visible precipitate; this apparently homogeneous but probably colloidal solution is an active catalyst. In any case, the colloidal solution, the solid precipitate or the unseparated mixture can be used as a catalyst. Alternatively, the precipitate may be separated and used as one component of a catalyst system; the other component being an organometallic compound such as an aluminum alkyl. If any of these Ziegler catalysts are produced from the same starting materials in the presence of an olefin, a more active catalyst is often produced than that produced in the absence of such a 1-olefin; this is not always the case, however.

Catalyst preparation for the Ziegler process may be carried out in one of 3 ways according to Berger and Boultbee:[322]

1. $TiCl_4$ and Et_3Al pass in separate streams directly into the polymerization reactor. They react slowly according to the equation:

$$Et_3Al + TiCl_4 \rightarrow Et_2AlCl + TiCl_3\ (insol) + Et\cdot$$

The free ethyl radical disproportionates or dimerizes. Since this reaction occurs concurrently with the polymerization reaction, catalyst composition is constantly changing during the process. Control of catalyst composition may be accomplished, however, by a scheme such as that shown in Figure 34. There ethylene is bubbled through $TiCl_4$ and through the aluminum compound and these two catalyst component-bearing ethylene streams are introduced simultaneously with ethylene into a reactor where polymerization occurs in the vapor phase.[154]

2. Et_3Al and $TiCl_4$ can be premixed and pre-reacted under conditions of controlled time, temperature, and concentration. The exact degree of reduction can be determined by analysis.

3. Et_3Al and $TiCl_4$ can be pre-reacted as in 2, above, but the solid produced (usually $TiCl_3$) can be filtered and washed and added to the polymerization reactor as a single constituent, the metal alkyl being added separately. By this technique, it is possible to add measured amounts of components which do not react further (e.g $EtAlCl_2 + TiCl_3 + TiCl_4$ where $EtAlCl_2$ and

$TiCl_4$ react, but very slowly) and which give a catalyst of constant composition throughout the polymerization process.

Categories 2 and 3 are discussed later under "Preformed Subhalide Catalysts."

In choosing the metal alkyl constituent of the Ziegler-type catalyst and in deciding the means for best introducing it, the reactivity of the alkyl with the transition metal halide must be taken into account. The reducing power of the aluminum alkyls falls in the order $Et_3Al > Pr_3\ Al > Bu_3Al$ with reducing power decreasing with an increase in the size of the alkyl radical. Also the reducing power is in the order $Et_3Al > Et_2\ AlX > EtAlX_2$, decreasing with increasing replacement of alkyl groups by halogens or other substituents.

The replacement of halogen in alkylaluminum compounds with alkoxy or aryloxy groups is believed to give a polymer with narrower molecular weight distribution.

The use of partially oxidized aluminum alkyls in conjunction with titanium halides has been patented by I.C.I..[217] From 15 to 35 percent of one alkyl group per aluminum alkyl molecule is oxidized to alkoxy groups by treatment with air at 40° to 60° C.

In addition to titanium and zirconium halides, such as $TiCl_4$ and $ZrCl_4$, other titanium compounds may be used. One of these is potassium fluotitanate, $K_2Ti\ F_6$[282] and another is potassium fluozirconate, $K_2Zr\ F_6$.

The molecular weight of the polymer produced varies with the nature of the organoaluminum compound in approximately the following manner:

Organoaluminum Compound	Intrinsic viscosity of Polymer
$AlEt_3$	11.4
Et_2AlCl	4.4
$EtAlCl_2$	2.0

The ratio of metal alkyl to transition halide in the Ziegler process gives very fine control of the average molecular weight of the polymer obtained. "Ratios" from 0.1 to 4.0 lead to inherent viscosities (measured in decalin at 120° C) between 2 and 15. The "ratio" is really that of aluminum-carbon bonds to $TiCl_4$, so that a lower ratio for an R_3Al system is equivalent to a higher mole ratio for an R_2AlCl system.

In general, the alkylaluminum compound is employed in mole quantities of 0.1 to 3.0 or more times the valence of the reducible metal in the halide—from 0.4 to 12.0 moles per mole of $TiCl_4$, for example. When the heavier metal compound is a metal acetyl acetonate, the organoaluminum compound is preferably used in larger proportions—up to 24 moles or more of triisobutyl aluminum per mole of zirconium acetylacetonate, for example.[187]

The use of 1.25 to 2.0 moles of ethylaluminum sesquichloride per mole of $TiCl_4$ in ethylene polymerization is specifically claimed in one patent.[191]

As pointed out by Gaylord and Mark[337] the physical and chemical factors related to the catalyst which must be controlled to regulate polymer properties are:

1. State of aggregation of the catalyst, particularly of the heavy metal component. Catalysts containing solids give higher percentages of isotactic polymers.

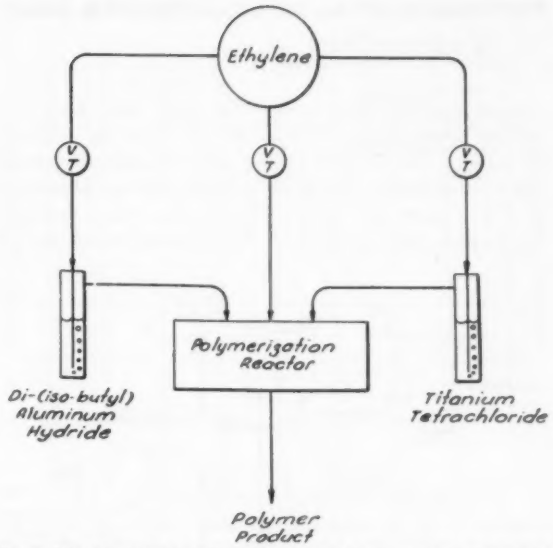

FIGURE 34—Ziegler catalyst composition can be controlled by using this scheme for catalyst introduction into the process.

2. Degree of dispersion of the catalyst in the solvent during polymerization. The finer the dispersion, the more amorphous the polymer that is produced.
3. Valence of heavy metal in the catalyst. Higher valences promote amorphous polymer formation.
4. Nature of substituents of the heavy metal. Thus, $TiBr_3$ gives more amorphous polymer than $TiCl_4$ because it is more soluble, even though in a lower valence state. Also, replacement of halogen by alkoxy groups in $TiCl_4$ gives a more soluble catalyst and more amorphous product.
5. Nature of substituents on the organometallic component. Longer alkyl groups or replacement of alkyl by halogen gives less isotactic polymer.
6. Size of the metal atom in the organometallic component. The smaller the radius the better for isotactic polymer production. Thus, beryllium is better than aluminum; aluminum better than magnesium; magnesium better than zinc.

Olefin Feed Composition. Water, oxygen, sulfur, and carbon dioxide are undesirable in the ethylene feed to the Ziegler process, according to Thomasson, McKetta, and Ponder.[359] Gaylord and Mark[337] have recommended that the olefin feed be treated with an aluminum alkyl to remove impurities prior to introduction to the polymerization reactor. On the other hand, small amounts of water can be used to reduce the molecular weight of the polymer in a controlled manner.

Oxygen content of the ethylene or the reaction mixture must be held below 500 - 1,000 ppm and preferably below 50 ppm. Oxygen decreases molecular weight of the polymer; up to a point it increases reaction rate, but above that point rate falls rapidly as the catalyst is oxidized to an inactive state. The effect of oxygen depends on the concentration of organoaluminum compound in the catalyst; the effect is greatest at low concentrations of organoaluminum compound.

The use of oxygen together with reaction time to

control polymer melt index has been described.[127] A desired melt index of 0.01 to 4.0 may be attained initially or during part of the polymerization by keeping oxygen below 200 ppm. By controlling the oxygen at 1 to 5 parts per million, the product has a desirable melt index during most of the polymerization period.

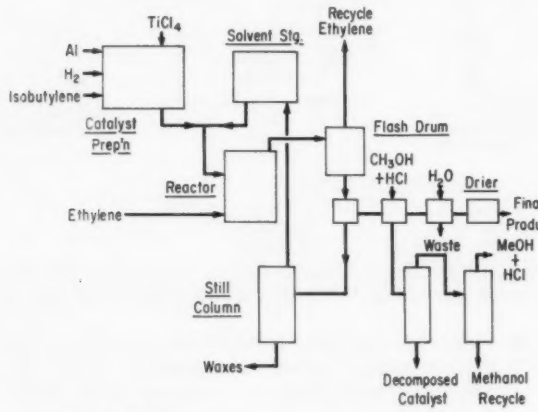

FIGURE 35—Typical flow diagram for the Ziegler polyethylene process.

This technique is particularly applicable to the control of polymer molecular weight at temperatures low enough to produce a product slurry—that is, in the range of 20° to 80° C. This technique may have advantages over molecular weight control by varying the catalyst component ratios where the latter may restrict catalyst activity, catalyst solubility, etc. The use of controlled amounts of oxygen ranging from 0.01 to 0.5 mole percent has also been specified when using bis-cyclopentadienyl titanium dichloride as a catalyst, adding an alkylaluminum compound in increments throughout the polymerization.[133]

Operating Conditions. The usual operating conditions for the Ziegler process involve near-atmospheric pressure and temperature of 50° to 75° C. Figure 35 shows the flow scheme of the Ziegler process and Figure 36 shows a continuous scheme for a similar process.

The metal halide is added to the metal alkyl in the solvent, which may typically be diesel oil, heptane or chlorobenzene. As the catalyst components react under agitation, a colored colloidal dispersion of a precipitated complex forms. That operation is carried out under a blanket of purified nitrogen. The actual polymerization reaction may be carried out in the same or a different vessel from that employed for catalyst preparation. Ethylene or other monomer is then introduced to the reaction vessel under slight pressure. Cooling is supplied to remove the heat of the exothermic reaction. The polymer forms as powder or granules which are insoluble at the reaction temperature. After completion of the reaction, the reactor is cooled and any unreacted monomer is vented. The reaction mass

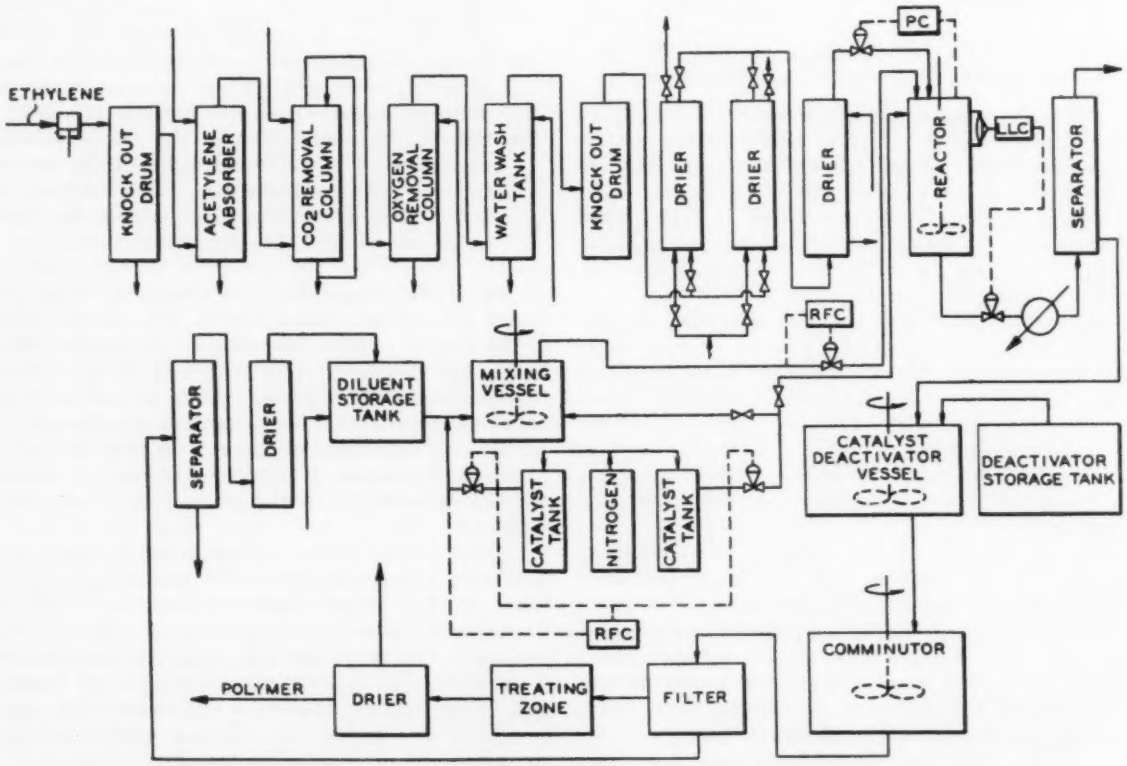

FIGURE 36—Flow scheme for a continuous Ziegler-type polyethylene process.

is then quenched with water or alcohol to remove any active metallic residues. The resulting aqueous slurry of polymer is filtered or centrifuged and the solid polymer dried.

Operation at atmospheric or near-atmospheric pressure is an essential feature of the Ziegler process and, indeed, it is frequently referred to as the low-pressure process. However, operation at 1,000 to 2,000 atmospheres and at relatively high temperatures of at least 175°C has the advantage of requiring only a small fraction of the catalyst required at near-atmospheric temperatures and pressures. The pounds of polymer per pound of catalyst are increased from 100 to 1,000 or more. The catalyst residue in the raw, unwashed polymer from such a high pressure process is only about 1,000 ppm.[187]

Operation under reflux conditions with the reaction zone maintained at 50° to 85° C and with continuous venting of non-condensable vapors from the top of the reflux condenser is claimed to be necessary to successful operation.[224]

Reaction times of 1 to 4 hours and product molecular weights ranging from 20,000 to 1 million are cited for various Zieger catalyst compositions by Gaylord and Mark.[337]

The solvent cited in the original Ziegler work was a diesel oil. Commonly, heptane has been specified in many patents on this type of process. However, it has been claimed[218] that the use of monochlorobenzene as a solvent eliminates a 30 to 60-minute induction period encountered when using heptane as a solvent and gives a higher catalyst efficiency in terms of pounds of polymer produced per pound of catalyst.

The combination of toluene as a reaction medium with methanol as a quenching agent is claimed to offer operating advantages.[272] Actually, the quenching agent plus the polymer wash liquors are combined and distilled to give a toluene-methanol azeotrope which is then used both as the quenching medium and as a washing medium for the polymer filter cake.

Dry hydrogen chloride may be used as a molecular weight control agent in this type of process.[260] The product made in the presence of 0.01 to 5.0 percent of added dry HCl has a higher melt index, lower residual unsaturation, and narrower molecular weight distribution than products made without added HCl.

Higher melt index (lower molecular weight) may also be obtained by

1. Increasing the ratio of $TiCl_4$ to R_3Al—which, however, magnifies ash removal and polymer product color problems
2. Increasing the temperature—which, however, increases resin deposits on the reactor walls
3. Increasing total catalyst concentration—which, however, is generally uneconomical
4. Decreasing reaction pressure—which, however, decreases productivity.

Lower molecular weights as well as increased yields result from the incorporation of boron fluoride or boron chloride in the $TiCl_4/AlR_3$ catalyst[303] as shown in Figure 37.

Ash Removal. In order to make a Ziegler-type polymer of satisfactory properties (particularly electrical properties, heat stability, light stability, and color)

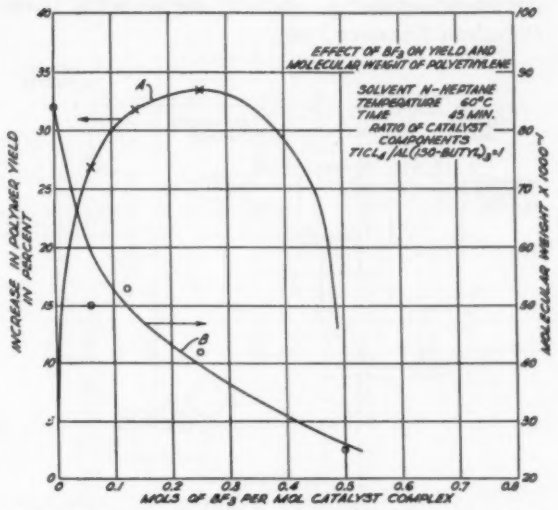
EFFECT OF BF_3 ON YIELD AND MOLECULAR WEIGHT OF POLYETHYLENE
SOLVENT N-HEPTANE
TEMPERATURE 60°C
TIME 45 MIN.
RATIO OF CATALYST COMPONENTS
$TiCl_4/Al(iso\text{-}BUTYL)_3=1$
INCREASE IN POLYMER YIELD IN PERCENT
MOLECULAR WEIGHT X 1000
MOLS OF BF_3 PER MOL CATALYST COMPLEX

FIGURE 37—Here's how boron trifluoride as an additive effects the yield and molecular weight in the Ziegler process.

and to prevent corrosion of process equipment employed in the fabrication of the polymer, it is necessary to purify it and remove any traces of catalyst. Such after-treatment of the polymer may involve filtration, preferably in the presence of air (which tends to lighten the color of the polymer product), to separate the polymer product from the reaction mass. This may be followed by sequential washing with hexane, isopropanol or water, acetone, and pentane prior to drying. When higher catalyst concentrations are used in the Ziegler process, some of the metallic compounds may be removed by extraction with HCl in methanol followed by washing with methanol or acetone. Repeated washings with butanol may also be used to decompose and remove the catalyst residue from the polymer product. A number of methods for ash removal have been proposed including extraction with alcohols, acids, bases, alkylene oxides, and complexing agents.

In general, three different physical techniques can be used:[171]

a. Dissolve the polymer and reprecipitate
b. Dissolve the impurities (leaving the polymer undissolved)
c. Melt the polymer and separate the solid and liquid phases.

Even so, catalyst residues over 50 ppm and frequently as substantial as 200 to 2,000 ppm by weight, depending on the molecular weight of the polymer, may still remain in the polymer products, even after such after-treating procedures. The statement has been made, however, that other than electrical-grade polymers can tolerate an ash content of 1,000 to 2,000 ppm.[235] Product improvement is, nonetheless, constantly being sought.

Thus, a combination of lithium methylate and methanol are claimed to be particularly useful in deactivating catalysts to reduce undersirable darkening of the polymer[151] but typical examples cited showed ash contents remaining after such treatment of 0.15 to as high as 0.65 precent (1,500 to 6,500 ppm).

Alcohol quenching, followed by refluxing with a sodium or potassium alkoxide, followed by several more

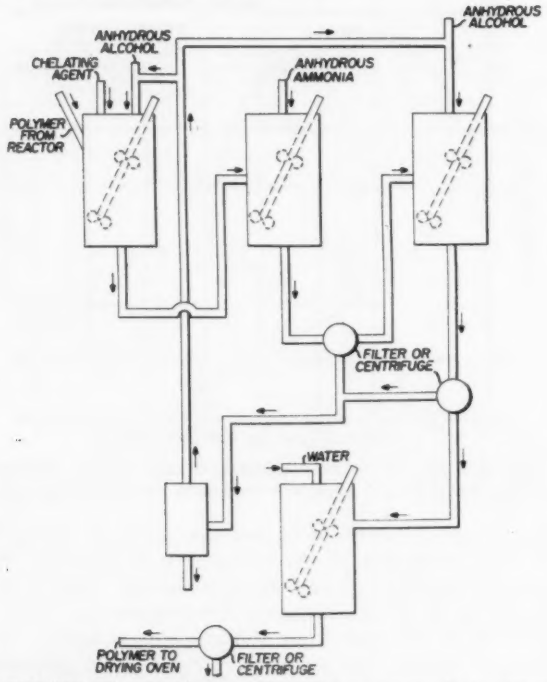

FIGURE 38—In this de-ashing scheme, ammonia treatment followed by alcohol treatment prior to subsequent alcohol and water washes removes the hydrogen halide acids formed by alcohol treatment alone.

alcohol washes at an elevated temperature are claimed to give a polymer product non-corrosive to steel molds or extrusion dies.[228]

Treatment with polyhydric alcohols in a ratio of 1.5 to 3.0 mols of polyhydric alcohol per mol of catalyst is quite effective.[287] The alcohol treatment is followed by water washes. Particularly good results are obtained if small amounts of a complex-forming organic acid (such as oxalic, lactic, glycolic, tartaric, and citric acid) is added to the first wash water. Polyvalent alcohol treatment will reduce ash content to 100 ppm and such alcohol treatment combined with the use of a complex-forming organic acid can cut ash content to 50 ppm.

One of the problems with alcohol treatment of polymers containing metal halides is that hydrogen halide acids are formed from the halogen present in the catalyst by the reaction

$$MX + ROH \rightarrow ROM + HX$$

Ammonia treatment following alcohol treatment of the reactor effluent, and prior to subsequent alcohol or water washes is claimed to eliminate this difficulty.[298] A process suitable for carrying this out is shown in Figure 38.

Careful temperature control (between 60° and 150° C) is claimed[302] to be particularly important in producing low ash content polymers by the use of aliphatic alcohols as treating agents.

Catalyst residues can be removed from polypropylene by grinding in a ball mill, for example, in the presence of liquid titanium tetrachloride[182] at room temperature. The residual titanium in the polymer is reduced below 100 ppm (as compared to 1,000 ppm after a methanol-alcoholic HNO_3-methanol wash sequence) and a solution of $TiCl_3$ in $TiCl_4$ recovered for use in subsequent $TiCl_3$ catalyst preparation.

Polymers containing residual solvent and 0.3 to 0.4 percent of residual catalyst may be treated with steam to remove the solvent. Mineral acid treatment can be used to cut the ash content to 1,000 to 2,000 ppm (0.1 to 0.2 percent). Alkaline washing instead of acid treatment will reduce the ash content to 500 to 1,000 ppm.[143]

Steam or air may be used in a fluidized bed process to de-ash polymers.[285] Air is employed at linear velocities of 0.15 to 0.3 feet per second or steam at velocities of 0.20 to 0.25 linear feet per second. Quenched polymers prior to such treatment averaged 1,000 to 5,000 ppm of residual chloride and analyzed less than 200 ppm after treatment; in addition, the color of the polymer was visibly improved.

A special cone-shaped separator tower has been devised for catalyst removal. The slurry of polymer, catalyst, and solvent from the reactor is sprayed downward into the tower just above a baffle as shown in Figure 39. The baffle divides the tower into a lower catalyst collection zone and an upper polymer disengaging zone. In a polypropylene process, propane and unreacted propylene are flashed off and leave the top of the tower. Additional propane and propylene are introduced through a second line at the base of the tower, sufficient to provide a 1 ft/sec gas velocity upward in the lower section of the tower. Polymer is thus entrained and carried up through the baffle; it falls back on the outward-sloping baffle and is removed. The heavier catalyst particles are not entrained and pass out the bottom of the tower.[288]

An improved catalyst cleanup procedure for Ziegler polymers which can reduce catalyst residue below 20 ppm has been described.[132] It involves treating the polymer first with a peroxide, lauroyl peroxide being particularly effective; this makes the catalyst residue reactive with fatty acids. Then the polymer is contacted with a C_4 to C_{20} fatty acid such as lauric acid. The heavy metal residues which are now in soluble organic acid salt form are removed by washing with a non-polar solvent such as benzene or hexane. This whole operation may be carried out at 60° to 100° C over a period of about four hours.

The use of oxygen-free water as a catalyst destroyer

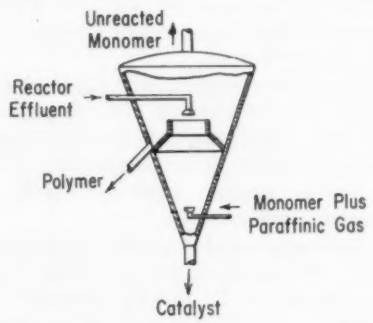

FIGURE 39—In this catalyst/polymer separation vessel, unreacted monomer goes overhead, catalyst out the bottom of the cone, and polymer is removed from the upper part of the partitioned cone.

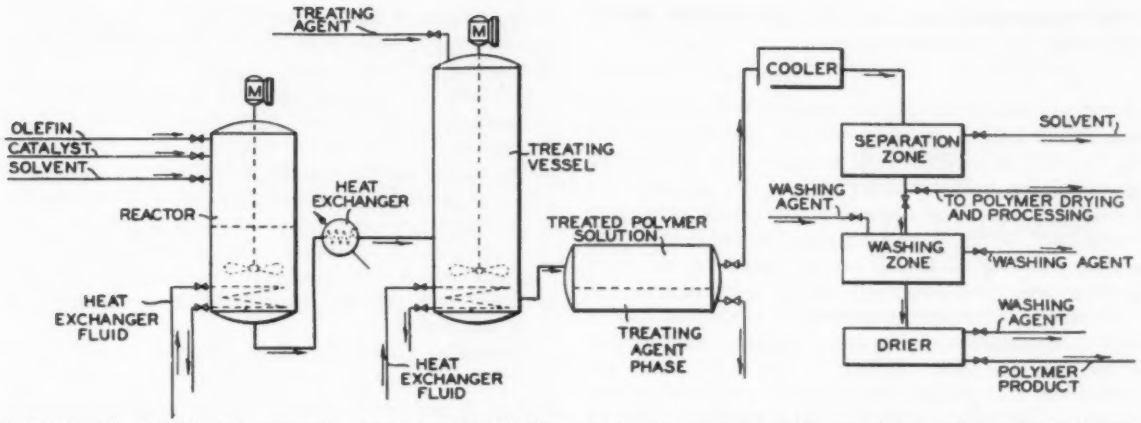

FIGURE 40—In this ash removal scheme for the Ziegler process, water used alone or in conjunction with other agents is claimed to yield polymers of low ash content and snow white color.

and subsequent polymer extractant is claimed to give a polymer product substantially free of inorganic residues.[235]

The use of water alone or in conjunction with other agents (such as butanol, ethyl acetate, acetic acid, aldehyde) in treating the polymer in solution (as distinguished from the solid polymer) is claimed to give low ash content and a snow white color.[192] See Figure 40. Treatment at 200° to 400° F with 1 to 5 volumes of washing agent per volume of polymer solution for 5 to 300 minutes reduces ash content to 200 to 600 ppm.

Polymer ash contents may be reduced to 5 to 100 ppm by treatment of the catalyst-containing polymer solution with an alcohol under pressure at 125° to 250° C, followed by contacting with a silica or alumina adsorbent.[200]

An aqueous hydrated colloidal silica may be used in ash removal.[244] When mixed with a polymer-solvent-catalyst residue mixture, it reacts with the catalyst residue to give a coarse, granular precipitate which is easily removed from the polymer solution by filtration. A polymer which would have contained 1,430 ppm of catalyst in the absence of any ash removal treatment was purified to 70-80 ppm ash by colloidal silica treatment. This is 95 percent removal of catalyst from the polymer.

A novel technique for aluminum recovery in organic form as a consequence of quenching and/or de-ashing involves the use of isobutylene as a treating agent.[315] It is believed that the long hydrocarbon chains formed in the polymerization reaction which are attached to the aluminum undergo an exchange reaction with isobutylene to give aluminum triisobutyl which can be recovered by distillation.

Other Metal Alkyl-Metal Halide Catalysts

"Soluble" Catalysts. The production of an apparently soluble Ziegler catalyst using aluminum trioctyl in conjunction with $TiCl_4$ is described above. Alternatively, bis-cyclopentadienyl titanium compounds may be incorporated to produce soluble Ziegler-type catalysts according to Hercules Powder Co.[133] Similarly, bis-cyclopentadienyl zirconium dichloride[308] and bis-cyclopentadienyl vanadium dichloride[319] have been patented as ethylene polymerization catalysts. (Gaylord and Mark[337] state, however, that these cyclopentadienyl metal catalysts require higher temperatures to polymerize propylene and then only produce dimers and trimers.) Still another way of making soluble catalysts is using a combination of a titanium compound, an aluminum halide and a tin alkyl or an aluminum alkyl. It is claimed that these soluble catalysts give higher, more uniform yields of purer and more readily purified polymer with superior electrical properties.

A monocyclopentadienyl titanium trihalide together with an alkylaluminum compound gives a soluble or colloidally dispersable ethylene polymerization catalyst.[280] It can be used at—10° to 100° C and at 1 to 50 atmospheres. It is claimed that such a composition is unaffected by significant amounts of oxygen.

Alkoxide-Containing Catalysts. The use of long chain alkyl orthotitanates in place of titanium halides in conjunction with C_2 to C_{12} mono- or di-alkyl aluminum halides is claimed to give improved yields, catalysts of improved storage stability, and polymers of improved color.[129] More specifically C_8 to C_{13} tetraalkyl orthotitanates are claimed to give much improved yields and better storage stability than when lower alkyl titanates are used. The orthotitanates are more soluble in organic solvents and more easily washed from the polymer than titanium tetrahalides, eliminating traces of catalyst which have a tendency to discolor the polymer. Such a catalyst may be used to polymerize C_2 to C_{10} olefins at temperatures of 60° to 100° C and pressures of 0 to 20 psig. The use of lower (C_1 to C_4) alkyl orthotitanates in combination with monoalkyl aluminum dihalides having 1 to 12 carbon atoms has also been patented for use at 25° to 130° C and 20 to 700 psi.[138] This latter patent points out that trialkyl aluminum compounds such as triethyl aluminum, are quite effective as catalysts in conjunction with titanium halides, but for some unknown reason, in combination with titanium tetraalkoxides do not produce solid polyethylene at all.

This latter point may be explained on the basis that some halogen must be present to create an effective catalyst. Empirical data supporting this are as follows:

a. Titanium isopropoxide and diethyl aluminum bromide make an active catalyst
b. Titanium-diisopropoxy dichloride and triisobutyl aluminum make an effective catalyst.[166]

Titanium tetrachloride, vanadium tetrachloride or

chromium trichloride can be combined with alkoxyalkyl aluminum halides to give effective catalysts.[236] The Al (X) R (OR′) compounds are prepared by reacting an aluminum halide with an ether in the presence of a reducing metal. The aluminum compound thus prepared and the Ti, V, or Cr halide can be heated with agitation at 80° C for 30 minutes prior to use; such pretreatment gives improved results, it is claimed.

Titanium, zirconium, hafnium, or vanadium halides may be combined with hexaalkyl distannoxanes to give active, easy-to-handle catalysts.[125] The stannoxanes are insensitive to moisture and oxygen compared to the aluminum alkyls which they replace. Polymerization of olefins up to C_8, but preferably in the C_2 to C_4 range proceeds at room temperature and atmospheric pressure using such a catalyst. Aromatic hydrocarbons are the preferred solvents, but chlorinated hydrocarbons such as CCl_4 are also suitable.

Containing Alkali Metals. The combination of alkyl, cycloalkyl, or aryl sodium or other alkalimetal compounds with titanium or zirconium di-, tri-, or tetrachloride permits operation of an ethylene polymerization process at mild temperatures of 10° to 80° C.[169]

The combination of titanium tetrachloride, sodium metal and acetylene gives a useful and economic catalyst.[178] Such a catalyst, when used for ethylene polymerization, is activated by the presence of higher olefins. Benzene, toluene, and cyclohexane are preferred reaction media and the preferred reaction temperature is 100° C.

Sodium metal and titanium tetrachloride constitute a catalyst mixture which can be promoted effectively with minor proportions of an aldehyde or ketone.[185]

Lithium metal and titanium tetrachloride constitute a mixture effective in polymerizing C_3 to C_{10} olefins at 150° to 250° C and 200 to 5,000 psi.[241] Replacement of lithium by sodium or potassium gives a mixture totally ineffective in polymerizing these higher olefins (although effective for ethylene). Replacement of $TiCl_4$ by $Ti(OR)_4$ similarly destroys catalyst activity.

The combination of a sodium alkyl (or sodium hydride or sodium metal) with titanium tetrachloride (or other Group IV to VIII salt) is claimed to be substantially improved by the incorporation of a mercaptan or a sulfide.[149] The mole ratio of sulfur compound to alkali reagent should be from 0.001 to 1.0.

The combination of titanium tetrachloride with sodium can be improved by the addition of aluminum cyanide, it is claimed.[297] Polymerization conditions are 0° to 250° C and 1 to 55 atmospheres.

The combination of a lithium aluminum alkyl with a titanium halide in a ratio of 1:2 to 1:4.5 has been claimed to give good control of polymer melt index.[145] From 0.5 to 50 percent of the titanium compound by weight of the ethylene monomer is sufficient to give high rates of polymerization. Temperatures of 20° to 100° C at pressures of one to five atmospheres in the presence of a cyclohexane solvent constitute the preferred conditions.

Containing Alkaline Earth Metals. Compounds of the alkaline earth metals of the formula Ar MX where M is calcium or barium are claimed[276] for use in conjunction with titanium, zirconium, or vanadium halides in ethylene polymerization.

Calcium hydride can be used in conjunction with titanium tetrachloride and aluminum chloride.[290] Such a catalyst is stated to be unique in that the average melt viscosity increases as the polymerization progresses. Thus, by controlling reaction time, with other variables held constant, it is possible to control polymer melt viscosity. This is in contrast to the usual $AlR_3/TiCl_4$ catalysts which are relatively uncontrollable so that polymer melt viscosity cannot be pre-determined or easily controlled.

Containing Group II_B Alkyls. Diphenylzinc in a 1 to 1 ratio with titanium tetrachloride may be used as a catalyst at 20° to 60° C and 15 to 200 psi pressure.[251] Diarylcadmium compounds may be similarly employed[252] as may di-alpha-naphthylzinc compounds.[253]

Containing Aluminum Metal. The combination of aluminum metal with titanium tetrachloride together with a peroxide gives an olefin polymerization catalyst which is active at 50° to 150° C and at pressures of 1 to 100 atmospheres, preferably in the presence of a solvent.[170] The addition of the oxygen compound affects both reaction rate and polymer properties.

An aluminum metal-aluminum halide-titanium compound catalyst can be greatly improved by the addition of sodium fluoride.[220] Increased polymerization rates and a higher degree of polymer crystallinity are claimed for this composition.

Aluminum metal, a titanium compound, and a tetra substituted ammonium salt constitute an effective catalyst for polymerizing C_2 to C_{10} olefins.[259] The process is carried out in a liquid solvent at —20° to +80° C and 50 to 700 psi. Similarly, aluminum metal, a titanium compound and an alkali fluoride may be used.[313]

A catalytic mixture of aluminum metal and $TiCl_4$ may be improved by the addition of a C_1 to C_4 alkyl halides.[316] Mono or dihalides may be used and chlorides and bromides are particularly preferred.

Containing Group IV_A Metals. Trialkyl germanium hydrides may be used in conjunction with $TiCl_4$.[312] Such catalysts are claimed to have particular advantage over conventional Ziegler compositions containing aluminum alkyls in the polymerization of higher olefins as shown by the following tabulation of yields of crystalline polymer:

	Aluminum Alkyl-Contg.	Germanium Alkyl-contg.
Polypropylene	50	80-90
Poly-3-methyl-1-butene	50	80-90

The reasons for this difference are not clearly understood, but germanium halides are less acidic than aluminum halides. The aluminum halides formed when AlR_3 and $TiCl_4$ are mixed may give acid-type catalysis leading to rubbery, non-crystalline polymers.

Tetraethyllead (TEL) may be combined with titanium tetrachloride and a peroxide to yield an effective olefin polymerization catalyst.[171]

Tetraphenyltin may be combined with $TiCl_4$ in a catalyst for the polymerization of ethylene, propylene, 1-butene, etc. Specifically this composition is pretreated at 150° to 250° C for 0.3 to 2.0 hours with hydrogen in the presence of a metal hydrogenation catalyst to impart increased catalytic activity.[277]

Containing Group V_A Halides. As noted earlier in the review, minor amounts of polyethylene were first produced with metallic catalysts by Fischer, who employed a mixture of aluminum, $AlCl_3$, and $TiCl_4$. More recently, it has been found that replacement of the aluminum chloride in the Fischer system with a phosphorous or antimony halide will polymerize C_2 to C_{10} olefins to solid polymers without simultaneous formation of any oily or waxy polymers.[279] The catalysts are quite specific in nature since the closely related stannic chloride gives very small yields of solid polymer. Further, triethyl phosphine and triethyl arsine are totally ineffective when used in place of the halides. Further, aluminum metal plus titanium alkoxides does not produce solid polymers but that same pair of constituents when combined with the phosphorous or antimony halides is a very effective catalyst for solid polymer production.

The chlorides of arsenic, antimony, and bismuth can be combined with organoaluminum compounds to give ethylene polymerization catalysts.[269] Similarly, the chlorides of gallium or indium may be combined with organoaluminum compounds or other organometallic compounds.[270]

Containing Other Transition Metals. A tungsten chloride, such as WCl_6, may be used in conjunction with a tin tetraalkyl or a lithium aluminum tetraalkyl in a mol ratio of chloride to alkyl of 1/4. Temperatures of 0° to 300° C and pressures of 1 to 200 atmospheres may be used.[174] Similarly, molybdenum pentachloride may be used in conjunction with a Grignard reagent, a lithium aluminum tetraalkyl or a tin tetraalkyl under similar reaction conditions.[277]

Molybdenum oxyhalides or hydroxyhalides or alkali molybdenum halides may be combined with organometal halides, such as alkylaluminum chlorides, to produce olefin polymer catalysts.[304]

Iron-based polymerization catalysts have been developed by Natta and his co-workers,[186] which consist of ferric chloride together with trialkyl or chlorodialkyl compounds of aluminum. Such a catalyst is effective in the polymerization of propylene and higher olefins.

Yttrium or scandium chlorides can be combined with lesser proportions of Grignard reagents, metal alkyls, metal hydrides, or alkali or alkaline earth metals to give effective ethylene polymerization catalysts.[239]

Osmium, iridium or platinum halides may be combined with an organometallic compound or an alkyl halide plus a reactive metal to give effective polymer catalysts.[283]

Cerium acetylacetonate may be combined with a metal alkyl such as aluminum triethyl to give a catalyst effective for the production of polyethylene, polypropylene, or ethylene-propylene copolymers.[301]

PREFORMED METAL SUBHALIDE CATALYSTS

Montecatini Process

It is pointed out by Friedlander and Resnick[336] that the Montecatini process for propylene polymerization has many points of similarity with the Muehlheim (Ziegler) process for polyethylene. Both employ titanium halide-aluminum alkyl catalysts. Further (and unlike the Phillips or Indiana processes) they operate at a temperature at which the polymer is insoluble in the reaction medium. However, the Montecatini process uses a pretreated catalyst rather than the precipitated catalyst of the Muehlheim process (which also produces polypropylene, but containing larger portions of amorphous polymer).

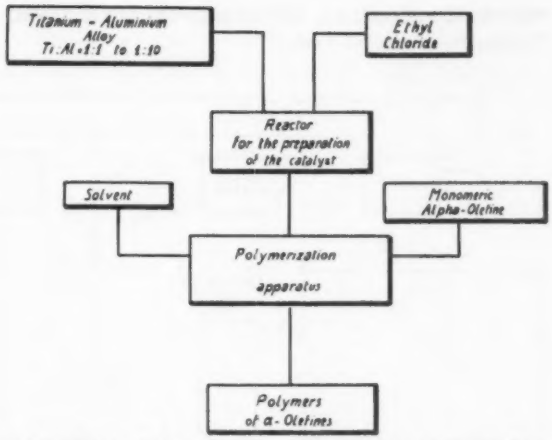

FIGURE 41—This schematic of the Natta process shows the use of the Titanium-Aluminum alloy with ethyl chloride for catalyst preparation.

The aluminum alkyl and titanium tetrachloride can be ground in a ball mill to 10-micron particle size, whereupon it is charged to the polymerization reactor. Alternatively, the reactor itself can be a ball mill in which the grinding action constantly prepares fresh catalyst surface and aids in continuous removal of polymer from the catalyst surface.

Thus $TiCl_3$ rather than $TiCl_4$ is the titanium halide charged to the polymerization reactor in the Montecatini process. Beyond that difference, the process closely parallels the Muehlheim polyethylene process, according to Friedlander and Resnick.[336]

Another route to a Natta catalyst involves reaction of a Ti-Al alloy with ethyl chloride.[234] The reaction may be carried out by grinding in a ball mill at 60° C. Alternatively a bed of alloy granules may be treated with ethyl chloride, used to polymerize olefin passed through it until activity falls off; the bed is then reactivated for further polymerization by the passage of more ethyl chloride. Figure 41 shows one embodiment of the Natta process in schematic form.

All this is somewhat startling in the light of statements[233] that "titanium trichloride is ineffective for converting ethylene to solid polymers" and[210] that "$TiCl_3$ alone is inactive" in propylene polymerization. The secret seems to be that $TiCl_3$ alone is inactive, but $TiCl_3$ even in the presence of a trace of an aluminum alkyl or other activator is active. However, it is also claimed that $TiCl_3$ alone is an active catalyst when used in the presence of ultrasonic waves.[221]

Esso Process

Olefins from C_2 to C_6 may be polymerized with preformed metal subhalides prepared by reacting $TiCl_4$, $TiBr_4$, $ZrCl_4$ and the like with aluminum triethyl, diethyl aluminum chloride, or mixtures thereof.[152] Separate solutions of the catalyst reactants are made in the same diluents or in two mutually miscible diluents. Then the two solutions are mixed and held at 100° to 175° F for 15 to 45 minutes. The ratio of aluminum compound to amphoteric metal halide can range from

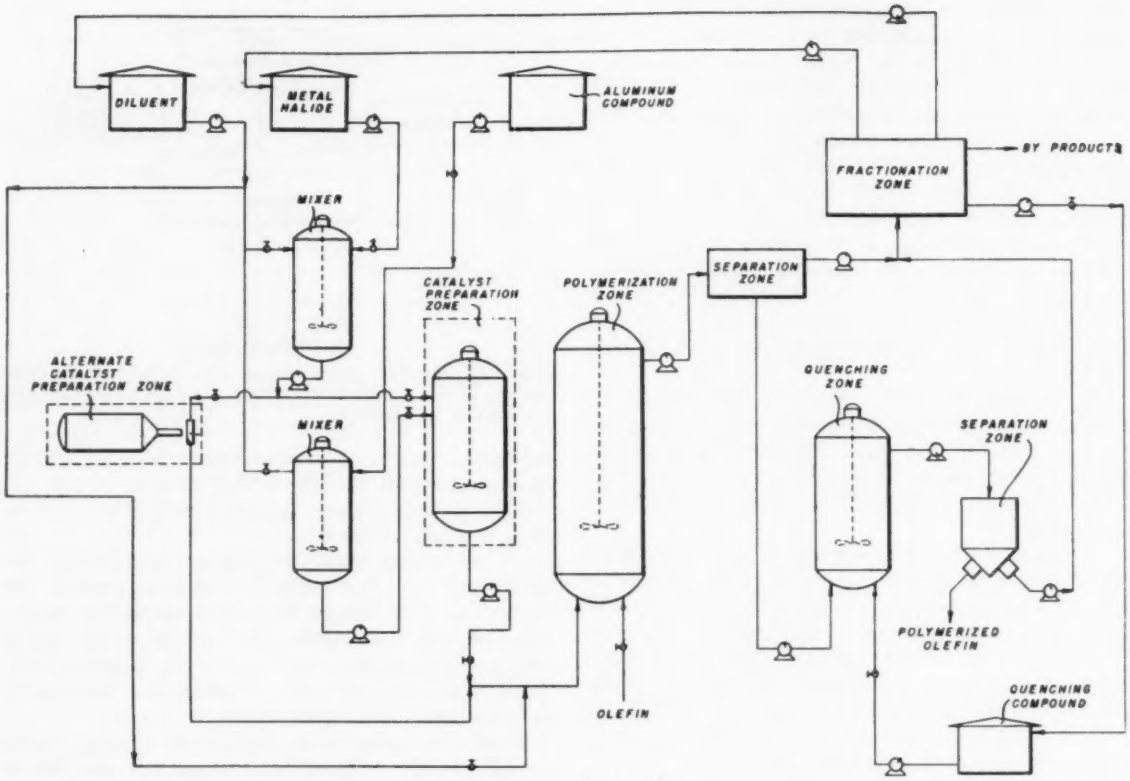

FIGURE 42—This Esso continuous process is claimed to give high yields of polymer of ash content as low as 100 ppm.

0.3/1 to 12/1 and should preferably be from 3/1 to 8/1.

There may or may not be added to the preformed amphoteric metal halide a chain propagating agent, such as aluminum alkyl. One patent[152] makes no provision for such an addition, whereas others[198, 210, 231] do. In another patent[232] subsequent additions of both aluminum alkyl and $TiCl_4$ are specified.

Reaction conditions are 120°-150° F, 1 to 5 atmospheres and a reaction time of one hour. The continuous process (See Figure 42) is claimed to give high yields of polymer of ash content as low as 100 ppm.[198] Chlorobenzene is a particularly preferred solvent. On the other hand, even better results are claimed if chlorobenzene is used only as a solvent in the catalyst preparation step and then n-heptane or another inert hydrocarbon liquid is used as the reaction diluent.

Some of the operating variables which may be used to effect control of this process[210] include:

a. Catalyst concentration
b. Temperature profile
c. Run time
d. Pressure
e. Extent of agitation

The addition of small amounts (100 to 10,000 ppm of olefin) of acetylene to give a lower molecular weight less rigid product may be employed.[216]

Admixture of aluminum alkyls with titanium tetrachloride prior to polymerization to produce an olefin polymerization catalyst is particularly critical with respect to the ratio of these catalyst ingredients as shown in Figure 43 in which catalyst efficiency in propylene polymerization is plotted against this ratio.[175]

The titanium tetrachloride in solution in a diluent may be at least partially reduced to the trichloride by

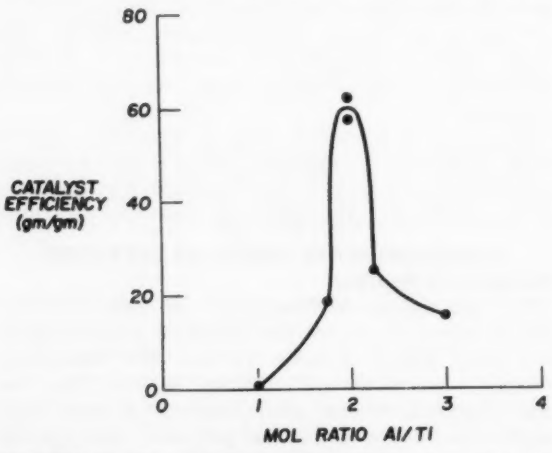

FIGURE 43—Notice the sharp change in catalyst efficiency with the aluminum/titanium mole ratio.

exposure to ionizing radiation.[152] An energy input of 5 to 500 watt hours of radiation per kilogram of solution should be employed; the energy may be supplied in the form of high energy electrons, beta rays, gamma rays, X-rays, and also recoil fragments of nuclear fission reactions.

The titanium trichloride prepared by reduction of titanium tetrachloride with an aluminum alkyl such as diethyl aluminum chloride is a comparatively stable brown salt. There is some tendency to change to a more stable violet or purple form; the latter is a catalyst, but only under more severe polymerization conditions than are required in the case of the brown salt. The desired brown salt may also be produced by reducing $TiCl_4$ in the vapor phase with an electric arc having a voltage of 35,000 to 250,000 volts at a temperature of less than 120° C; such arcs are generally characterized as visible electric arcs.[231]

Reduction of $TiCl_4$ with titanium metal at about 400° C gives violet crystalline $TiCl_3$. This material plus excess unreacted titanium metal is then activated by an aluminum alkyl to give an effective polymerization catalyst.[210]

The recovery of polymers of reduced ash content from the Esso process may be accomplished by quenching the catalyst after reaction with a tetrahalomethane, a hexahaloethane, or a C_1 to C_4 alkyl hypochlorite.[152] Carbon tetrachloride is a particularly preferred quenching medium.

Catalyst removal from $TiCl_3$ catalyzed polypropylene may be achieved by washing the reaction mixture with a saturated aqueous oxalic acid solution at 10° to 100° C.[255]

Other Preformed Subhalide Catalyst Processes

Aluminum metal may be heated with aluminum chloride in a ratio between 1:4 and 2:1 at 200°-220° C in an inert hydrocarbon diluent and in the absence of olefins to give a catalyst.[189] This catalyst is employed in a polymerization process at temperatures of 90°-110° C in batch operations or 140° C in continuous operations under a pressure of 10 to 50 atmospheres.

A mixture of titanium trichloride with a dialkylaluminum halide may be appreciably improved in effectiveness by the addition of 0.2 mol of sodium chloride per mol of dialkylaluminum halide.[246] The sodium chloride addition improves polymerization rate as well as the torsional rigidity and Rockwell hardness of the polymer. Operating conditions employed are 0°-100° C and 15-500 psi pressure. A mixture of titanium trichloride with an alkylaluminum sesquihalide (the name given to equal proportions of mono- and dialkylaluminum halides obtained by reacting aluminum with alkyl halides) is similarly improved by the addition of a group I or II halide.[247] At least 0.75 moles of the alkali or alkaline earth halide are used per mole of alkylaluminum dihalide in the aluminum sesquihalide.

Molecular weight control, and particularly suppression of undesirable high molecular weight fractions can be achieved when using preformed subhalide catalyst by adding a small amount (0.1 mol per mol of subhalide) of a hydrocarbon having an acidic hydrogen atom to the reaction solvent.[266] Examples of such materials are cyclopentadiene, fluorene, indene, and triphenylmethane.

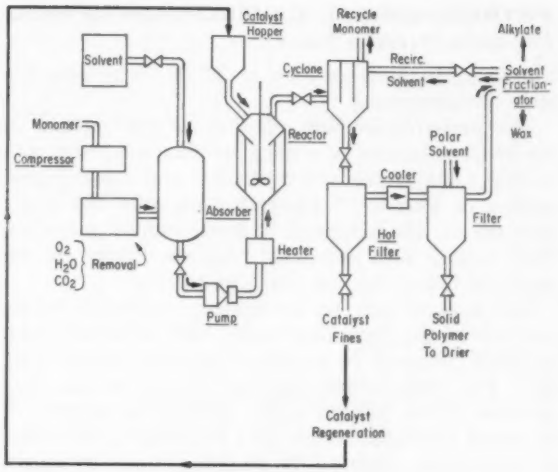

FIGURE 44—This typical metal oxide catalyzed process is generally applicable to the commercially important Phillips and Indiana catalysts.

Titanium dichloride alone is stated to be an effective catalyst for converting ethylene to solid polymers.[238] However, when $AlCl_3$ is used in combination with $TiCl_2$, the reaction rate is increased tenfold.[223]

The fact that $TiCl_2$ is a catalyst alone for ethylene polymerization and that $TiCl_3$ is not may well be tied in with close fitting of certain lattice parameters in the catalyst with interatomic distances in the adsorbed or complexed monomer molecules. The Ti-Cl bond distance in $TiCl_2$ is 2.14 Angstrom units and is 1.90 Angstrom units in $TiCl_3$, for example.

METAL OXIDE CATALYSTS

This category includes the commercially important Phillips (chromia-silica-alumina) and Indiana (Group V and VI oxides on alumina) catalysts. A typical flow scheme for this general type of process is shown in Figure 44.[329]

Phillips Process

The Phillips process has been described in the literature by Clark, Hogan, Banks, and Lanning,[327] polymer properties by Jones and Boeke,[344] and the molecular structure of the polymer by Smith.[356]

Although not pertinent to the major theme of this review, it is interesting to note that a nickel oxide on silica catalyst developed by Phillips Petroleum and described by Hogan, Banks, Lanning, and Clark[342] may be used to dimerize and trimerize ethylene at 70°-90° C and under a pressure of 40 atmospheres.

Catalyst Composition. The Phillips catalyst for the production of solid olefin polymers consists of chromium oxide associated with at least one oxide selected from the group consisting of silica, alumina, zirconia, and thoria. The chromium in the chromium oxide is usually placed in the hexavalent state by a special activation treatment. Chromium contents of such catalysts above 10 weight percent appear to have little added advantage for the polymerization of ethylene. For the polymerization of propylene and higher olefins, however,

chromium contents as high as 25 or 30 percent are often advantageous.

The preferred support material for the chromia in the Phillips catalyst is a silica-alumina composite containing a major proportion of silica and a minor proportion of alumina.[130] Lower surface area and larger pore size are characteristics of better support materials. High surface area and small pore size hinder the removal of heavy polymer from the catalyst.

The support can be pretreated, preferably before addition of the chromium oxide, with a fluoride such as NH_4F, followed by heating to remove residual fluoride. This pretreatment gives a catalyst which, after addition of the chromic oxide, produces a polymer of increased molecular weight and flexibility. From 0.001 to 0.2 parts by weight of the fluoride per part by weight of the oxide treated produces the improved results.[130]

Strontium oxide in a proportion of 0.5 to 2.0 gram atoms of strontium per gram atom of chromium is particularly valuable as a stabilizing agent to retard the decline of activity of the Phillips catalyst in use.[153]

The activation step is an oxidation with air or with steam plus air which converts the chromium in the catalyst to the hexavalent state. Preferred conditions are 650° C for 10 hours using a steam-air mixture containing 5 percent of steam. Temperatures of activation can range from 450°F to 1500° F, and preferably from 750° F to 1500° F. The time of activation can range from about a second at the highest temperatures to 50 hours or more at the lowest temperatures in that range. Periods of 3 to 10 hours or more are common.[130] The use of an activation temperature in the lower part of the temperature range gives a higher molecular weight product containing larger proportions of solid polymer, but longer activation times are required at such lower temperatures.

Olefin Feed Materials. The supported chromium oxide catalysts developed by Phillips polymerize all 1-olefins with branching no closer than the 4-position to the double bond and containing 8 carbon atoms or less. Thus, 1-hexene, 1-heptene and 1-octene produce branched polymers ranging from tacky semi-solids to viscous liquids and relatively low yields of normally solid polymer. However, 4-methyl-1-pentene gives a hard, brittle, solid polymer. Branching in the monomer closer than the 4-position (in 3-methyl-1-butene, for example) gives small amounts of dimers and trimers, but no high polymers.

Solid polymer as used in the Phillips patents refers to the higher molecular weight portion of the semi-solid fraction of the polymer produced and is that insoluble material left after extraction with n-pentane or MIBK. Thus, polypropylene prepared over the Phillips catalyst[130] may contain 10-20 percent by weight of an oil boiling from 400° to 900°F, the balance of the product contains both tacky and solid polymer. Polymers of 1-butene, 1-pentene, and 4-methyl-1-pentene are similar to those from propylene. Copolymers of ethylene with 1-olefins such as propylene and 1-butene are branched, the degree and length of branching depending on the amount and nature of the comonomer used. Ethylene homopolymers, on the other hand, are linear.

Water vapor, oxygen, carbon monoxide, and most

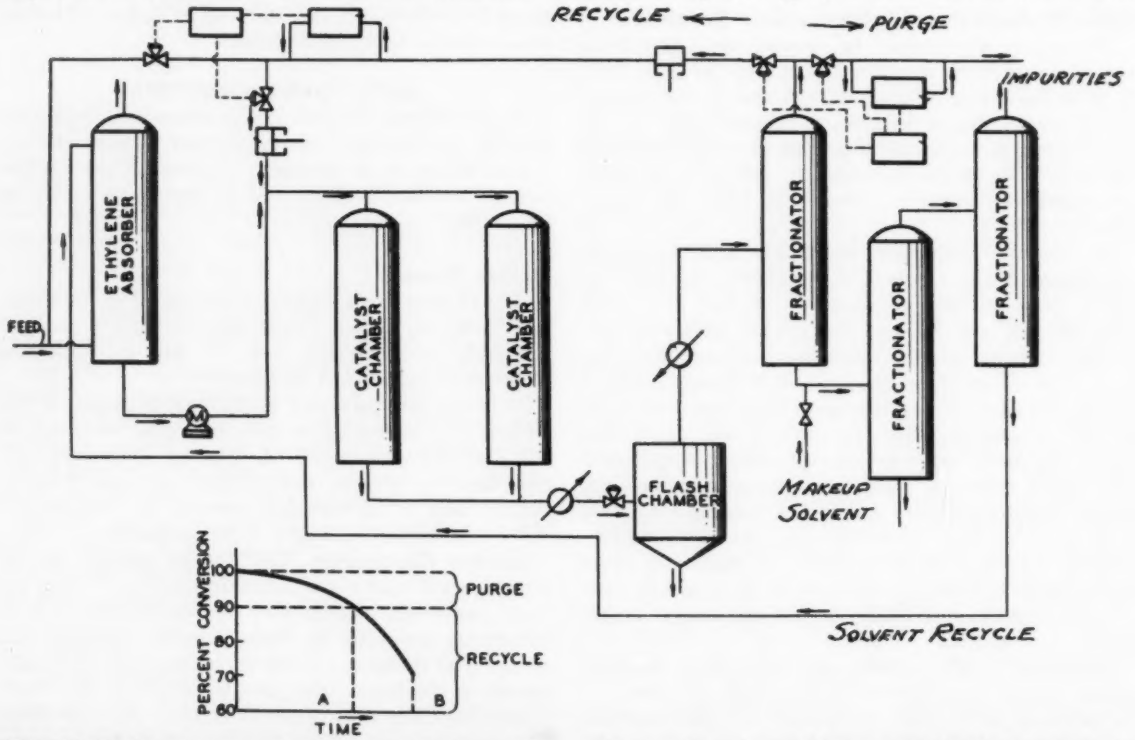

FIGURE 45—Here is one method for controlling impurities in the Phillips system which vents the unreacted olefin stream when catalyst activity is high and recycles it when catalyst activity drops below a predetermined level. Notice also that the solvent is fractionated before introduction to the reactor.

compounds of sulfur, of nitrogen, and of halogens, act as poisons for the Phillips catalyst. Their concentrations should be below 100 ppm.[130]

One technique for operating provides for the minimization of impurities in the reaction system by venting the unreacted olefin stream from the system when the catalyst activity is high and the olefin concentration in that stream is low. Then, when catalyst activity falls below a certain predetermined value, the unreacted fraction is recycled. Further, the solvent is subjected to fractionation prior to introduction to the reactor as shown in Figure 45.[163]

A technique which has been described in connection with the Phillips process[131] but which can equally well be applied to other olefin polymerization processes is one for handling a mixed olefin feed. Ethylene or other desired monomer can be absorbed from a gas mixture by a solvent and that solvent-olefin mixture then subjected directly to polymerizing conditions. When other olefins (such as propylene in ethylene) are present in undesirable amounts, the solvent mixture may first be subjected to a polymerization step to produce liquid (e.g. gasoline range) polymer and then passed to the polyolefin resin catalyst. Indeed a very similar scheme has been patented by Standard Oil Company (Indiana).[238]

Operating Conditions. The operating temperatures in the Phillips process range from 150° to 400°F. Pressures of about 500 psi are common, but may range from 300 to 700 psi. The feed rate may range from 0.1 to 20 liquid hourly space velocity. Reaction diluents are preferably paraffins or cycloparaffins; preferred are C_5 to C_{12} paraffins, but lighter hydrocarbons are effective—even methane or ethane alone in gas phase contacting or in mixtures with heavier paraffins in liquid-phase contacting.

Three major factors control molecular weight of polymer in the Phillips process:

1. Temperature of catalyst activation. Molecular weight decreases with increasing activation temperature
2. Reaction temperature. Molecular weight decreases with increasing reaction temperature
3. Reaction pressure. Molecular weight increases with increased pressure.

Fixed-Bed Operation. Fixed-bed operation (See Figure 46)[130] is ordinarily limited to the production of low molecular weight (5000 to 20,000) brittle polymer at reaction temperatures of 150°-180°C and ethylene concentrations in solvent of 2-4 percent. Lower temperatures and higher ethylene concentrations give higher molecular weight polymer, but catalyst bed plugging and catalyst spalling become severe. When polymer of 10,000-15,000 molecular weight is produced, reaction cycles of 50 hours or longer can be operated. Periodically reversing the direction of flow of the feed through the catalyst bed aids in distributing the heavy polymer over the catalyst and extends the time which the catalyst can be used before regeneration is required.[181] Another technique for circumventing excessive polymer deposition in the upstream portion of the reactor is to use a catalyst mass of graded composition[271] with a lower chromium oxide concentration in the upstream portion and a higher concentration downstream. The catalyst can be regenerated with air in situ and used over and over again for many cycles.

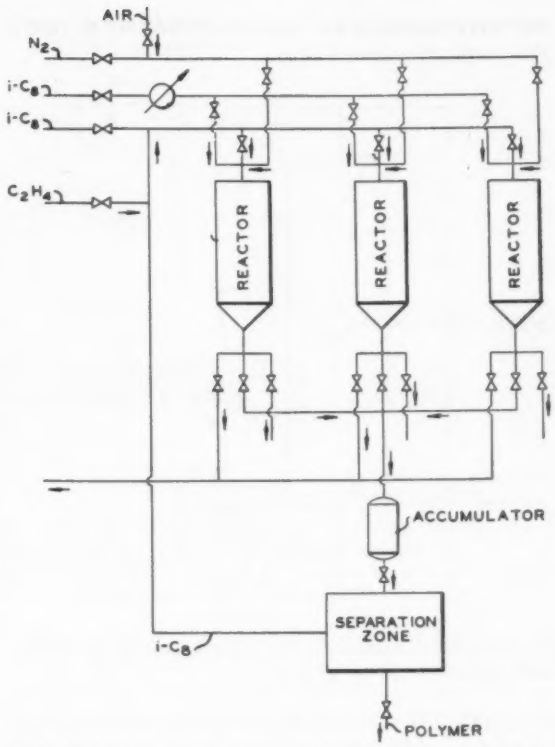

FIGURE 46—Flow diagram for the Phillips fixed-bed process.

When polymerizing ethylene in fixed-bed operations, the preferred operating temperature range is 275° to 375°F; the preferred range for propylene and higher olefins is 150° to 250° F.[130] Liquid phase operations over a fixed-bed catalyst are preferably conducted at a liquid hourly space velocity from 1.0 to 6.0.

Regeneration of the fixed-bed catalyst is preferably carried out in such a manner that contact of the catalyst with water vapor is avoided during the regeneration process.[150] This may be accomplished by preparing combustion gas, quenching or otherwise cooling it, drying it and using the dry gas to cool catalyst which has just been regenerated by burning with dry combustion gas plus a small amount of air. The partially heated gas from the cooling operation is heated by indirect heat exchange, air is added, and is used in regeneration.

Moving-Bed Operation. Moving or expanded-bed operation may be carried out by countercurrently contacting a slowly gravitating bed of the catalyst with liquid feed. This makes it possible to utilize the catalyst over longer periods of time before regeneration is necessary and entirely prevents plugging of the catalyst bed which eventually occurs in fixed-bed operation.

The olefin-containing feed together with a hydrocarbon solvent, such as n-pentane or isooctane, under sufficient pressure to maintain the liquid phase, is charged into the bottom of the reactor and moved upward at a linear velocity sufficient to give some expansion of the bed to prevent plugging by polymer accumulation,

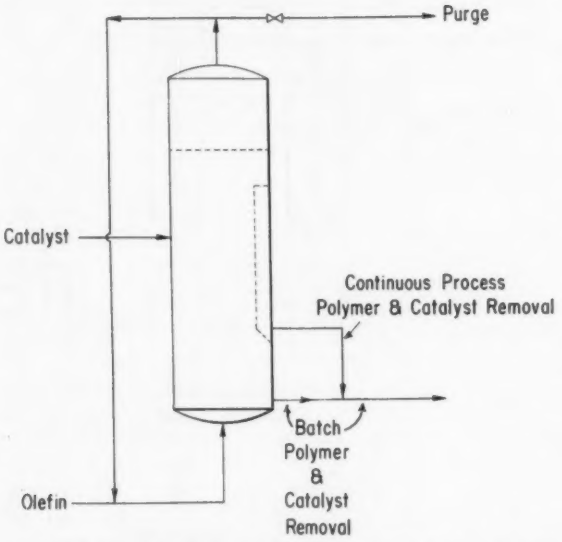

FIGURE 47—Schematic of the reactor used in the Phillips fluidized-bed gas phase process.

but insufficient to cause substantial top-to-bottom mixing of the catalyst.[130] In this type of operation, it is possible to maintain a top bed temperature of 100°-150°F and a bottom bed temperature in the same range while the middle section of the bed is maintained in the 200°-250°F range when polymerizing propylene or higher 1-olefins. Such operation produces more high molecular weight polymer in the top and bottom sections and increases the yield of solid polymer. The feed cools the hotter catalyst coming down from the mid-section and cool catalyst entering the top cools the exit liquid.

In the moving-bed process, the liquid feed rate is maintained at 2 to 6 in terms of liquid hourly space velocity, and the catalyst at an hourly space velocity of 0.1 to 0.5. The olefin concentration in the feed may vary from 0.1 to 25 percent.

Polymer remaining on the catalyst can be recovered, at least in part, by treatment of the catalyst with a solvent at a temperature above the reaction temperature or by stripping the catalyst with inert gas at a still higher temperature (700° to 1100°F or higher), the effluent stripping gas being cooled to condense polymer removed therein.

Fluidized-Bed Operation. A fluidized-bed gas phase version of the Phillips process has also been described.[164] Catalyst having a particle size in the range of 40 to 100 mesh is preferred, although finer (e.g. microspheroidal) particles may be used. The preferred reaction temperature is 200° to 230°F, which is just below the polymer melting point of 240° to 260°F. The preferred operating pressure range is 25 to 500 psig. A linear velocity of 0.2 to 0.5 ft/sec may be used in fluidized fixed bed operation and a linear velocity of 0.5 to 1.0 ft/sec may be used if dilute phase operation is desired. The reaction time may vary from 1 second to 20 minutes. The reactor is shown schematically in Figure 47.

A particular technique is suggested[164] to prevent agglomeration of catalyst particles by polymer. This involves initial operation of fresh catalyst for 30 minutes to 2 hours at a pressure from 25 to 80 percent of the full process operating pressure. This pre-conditioning step builds up a small amount of polymer which then prevents further agglomeration. This step may be carried out in a first fluidized reactor, delivering the conditioned catalyst to a second polymerization reactor.

Slurry Process. In slurry operation (See Figure 48), high molecular weight polymer (40,000 and higher) can be produced at temperatures below 150°C and at high ethylene concentrations.

When polymerizing ethylene, the preferred operating temperature range in mobile catalyst operations such as the slurry process is 175° to 350°F; it is 180°-200°F for propylene and higher olefins. These ranges are somewhat lower (25° to 50°F lower) than for fixed-bed operations. Solvent and a small amount of fine catalyst (0.01 to 10 percent and preferably 0.2 to 0.6 percent by weight of the solvent) are charged to the reactor. Operation is carried out at 400 to 500 psi.

The catalyst can be maintained in suspension by a mechanical agitation device and/or by virtue of the velocity of the incoming feed or diluent. In this type of operation, a large part of the polymer remains associated with the catalyst which is withdrawn from the reaction zone as a slurry.[130] Polymer is removed, dissolved in additional solvent, and filtered to remove catalyst.

Stripped catalyst can be recycled and/or regenerated. Regeneration can be accomplished by controlled oxidation. However, catalyst productivity is high enough that it may be economical to discard the catalyst. In some polymer products, such as those pigmented with carbon black, it may not even be necessary to separate the catalyst from the polymer, although polymer stability might pose some problems. Polymer is recovered from the filtrate by cooling to effect precipitation, filtering and drying.

Figure 49 shows a control scheme for the Phillips surry process.[245] In this scheme, the rate of flow of unreacted 1-olefin from the separator following the reactor is used to control the catalyst feed, catalyst feed being varied to hold the quantity of unreacted olefin constant.

In another aspect of control of the Phillips process, catalyst concentration in the catalyst slurry feed may

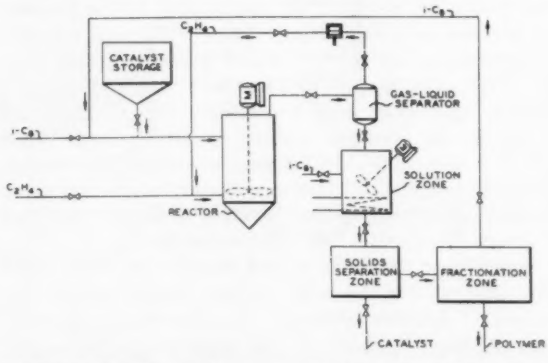

FIGURE 48—Using this arrangement of the Phillips slurry process, high molecular weight polymer can be produced.

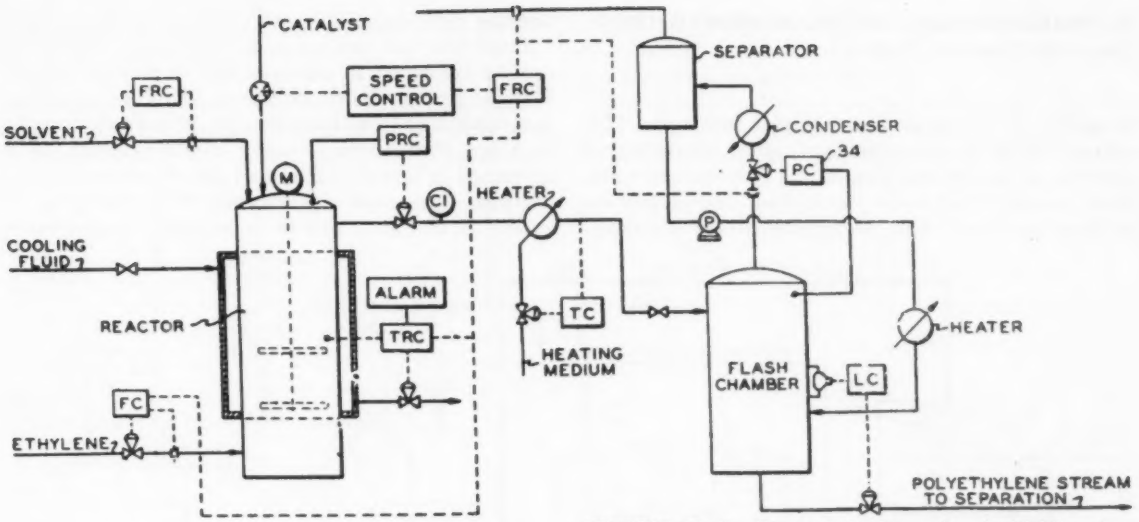

FIGURE 49—In this control scheme for the Phillips slurry process, the rate of flow of unreacted olefin from the separator is used to control the catalyst feed which is varied to hold the quantity of unreacted olefin constant.

be controlled by a device which senses the capacitance of the catalyst slurry and provides an impulse which is used to regulate the ratio of solvent to solids in the slurry.[278] See Figure 50.

Polymerization catalyst recovery in the Phillips slurry process may be accomplished by a two-stage centrifugation process[268] as shown in Figure 51. The catalyst-containing polymer solution at 200°-400°F is introduced to a first centrifuging zone under inert gas pressure. From that zone, the first product is a substantially catalyst-free polymer solution and the second product is a mixture of catalyst, solvent and polymer. The first stream goes to a recovery zone where solvent is recovered from the polymer. The second, or underflow, product is heated until all polymer is in solution and passed to a second centrifuge where one product is polymer, solvent, plus a small amount of catalyst; that stream is recycled to the first stage centrifuge. The second product from the second stage is a solvent stream rich in catalyst. Additional solids are added to that stream which then goes to a dryer from which solvent may be recovered.

Regeneration of the catalyst used in the slurry process may be accomplished, when desired by the scheme shown in Figure 52.[156] In this process, a filter aid is added to the slurry of polymer and catalyst in the reaction diluent. The catalyst plus filter aid are then separated from the polymer and diluent by filtration. The catalyst is regenerated in a fluid bed oxidation step. The filter aid is recovered from the fluid regenerator off-gas and regenerated catalyst is drawn off from the bottom of the fluid bed and recycled to the polymerization process.

The structures of polymers prepared by the fixed-bed and slurry variations of the Phillips process are remarkably different:[130]

Process	Slurry	Fixed-bed
Temp., °C	120-160	150-190
Crystallinity, %	94	92
Double bonds/ 1000 C/atoms	1.5	4.8
CH_3 group/ 1000 C/atoms	2±2	16±2
Unsaturation, %		
$RCH=CH_2$	94±2	7±2
$RCH=CHR'$	6±2	93±2
$RR'C=CH_2$	<2	<1

Thus, although the percent crystallinity is very similar for the products from the slurry and fixed-bed processes, the degree of chain branching and the nature of the olefinic structures in the polymers are quite different.

Curphey[329] points out that Phillips polymers produced over solid oxide catalysts have reduced stereo-

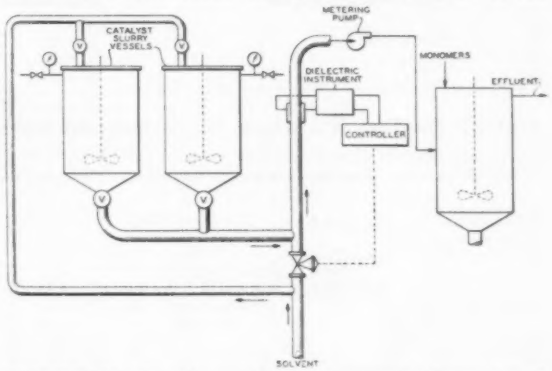

FIGURE 50—In this catalyst feed control scheme for the Phillips process, the catalyst concentration in the catalyst slurry feed is controlled by sensing the capacitance of the catalyst slurry and regulating the ratio of solvent to solids in the slurry.

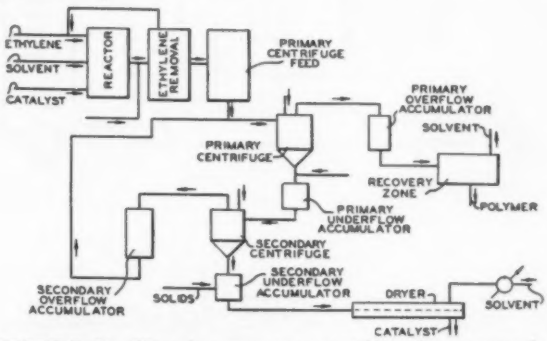

FIGURE 51—Here is a two-stage centrifugation process for recovery of polymerization catalyst in the Phillips process.

specificity, as compared to Ziegler polymers. This reduced degree of stereospecificity can be interpreted as evidence of amorphous sites in the polymer structure, which would facilitate plastic flow and improving molding operations. Also, amorphous sites would facilitate the inclusion of dyes and pigments in the polymer.

Fixed-bed (or moving bed) and slurry operations can be combined in one patented variation[305] of the Phillips process shown in Figure 53. The reaction is first conducted in a slurry reactor. The fixed (or moving) bed then serves to carry on the reaction (with unreacted or added olefins) and also to remove catalyst particles. The fixed (or moving) bed reactors are valved so that they can be regenerated. Regeneration

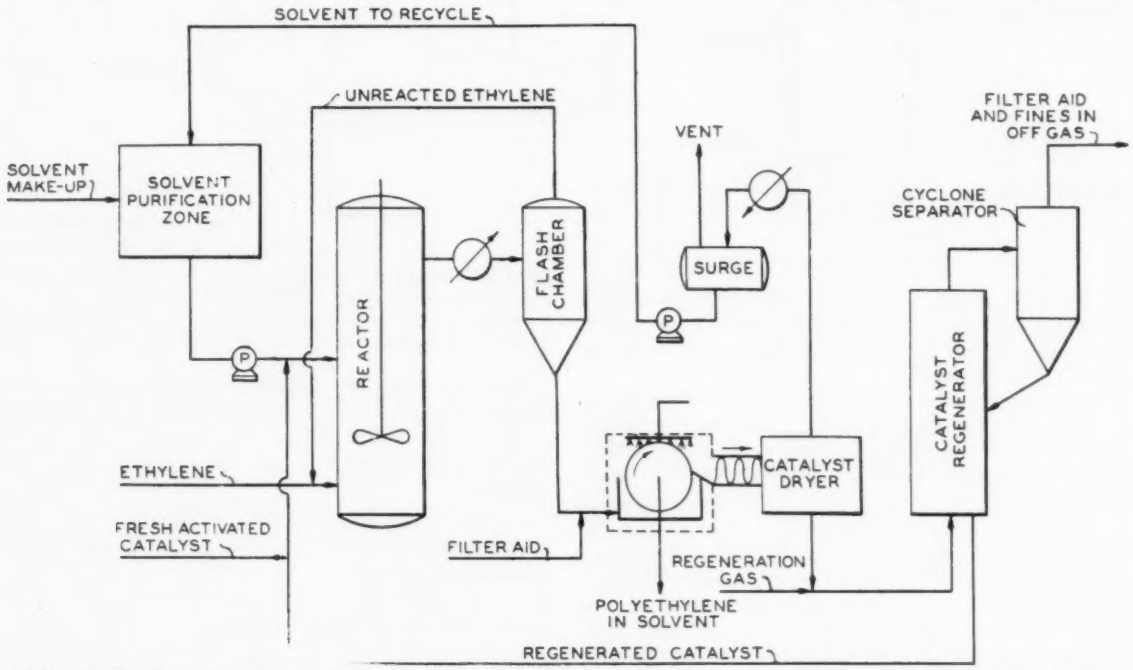

FIGURE 52—Here is a scheme for recovery and regeneration of the catalyst used in the Phillips slurry Process.

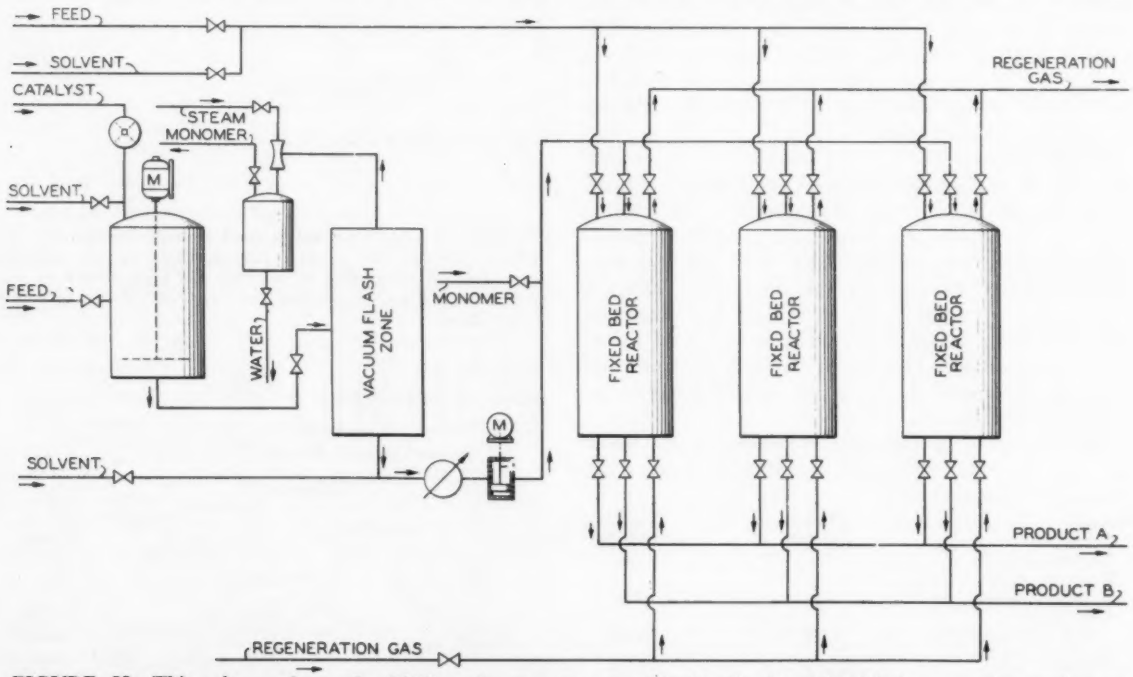

FIGURE 53—This scheme shows the Phillips slurry process combined with the pelleted-bed process for continuous polymer production.

gases are passed through at a rate sufficient to entrain and carry away catalyst fines.

Polymer Recovery. Separation of polymer from the solvent in the Phillips process may be carried out by evaporation of the solvent followed by extraction of the tacky polymer with n-pentane or MIBK at room temperature to remove any greasy or waxy materials and leave the solid polymer.

It may also be carried out by cooling the total reactor effluent from the polymerization temperature of over 200° (or even over 300) °F to about 150° F,

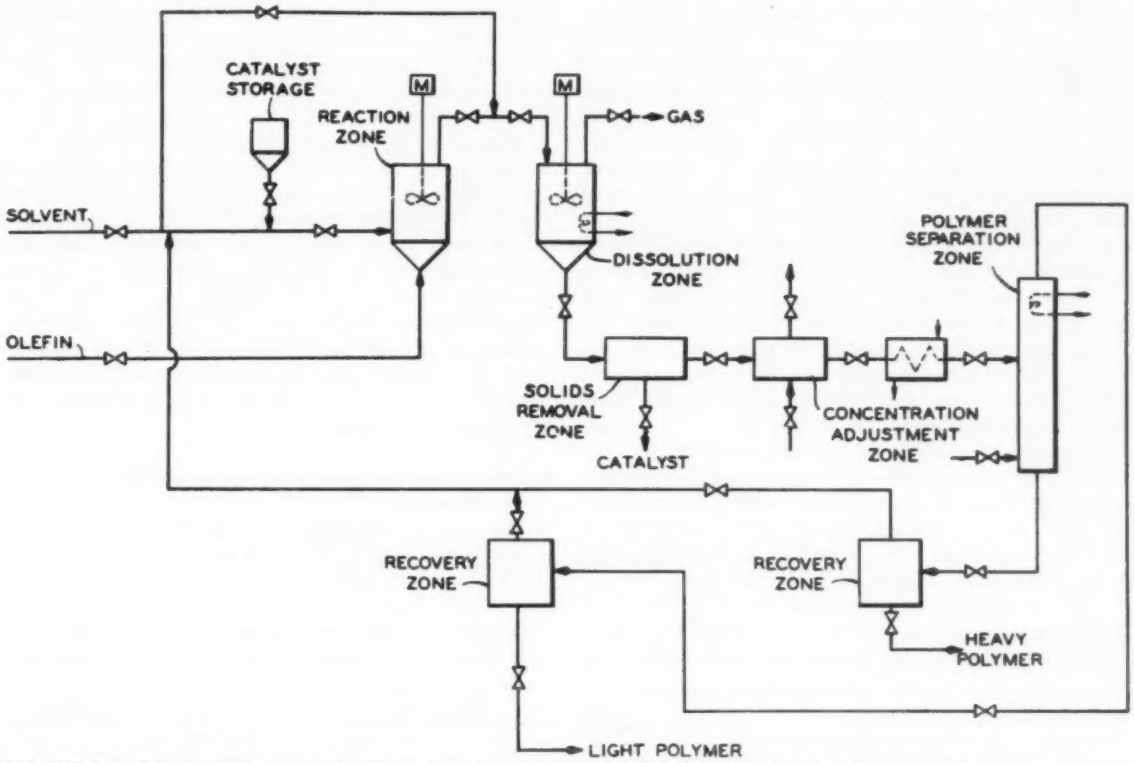

FIGURE 54—Polymer is recovered in this step of the Phillips process by heating the polymer-slurry catalyst-solvent, separating the solvent-rich and polymer-rich phases and fractionating the polymer from the solvent.

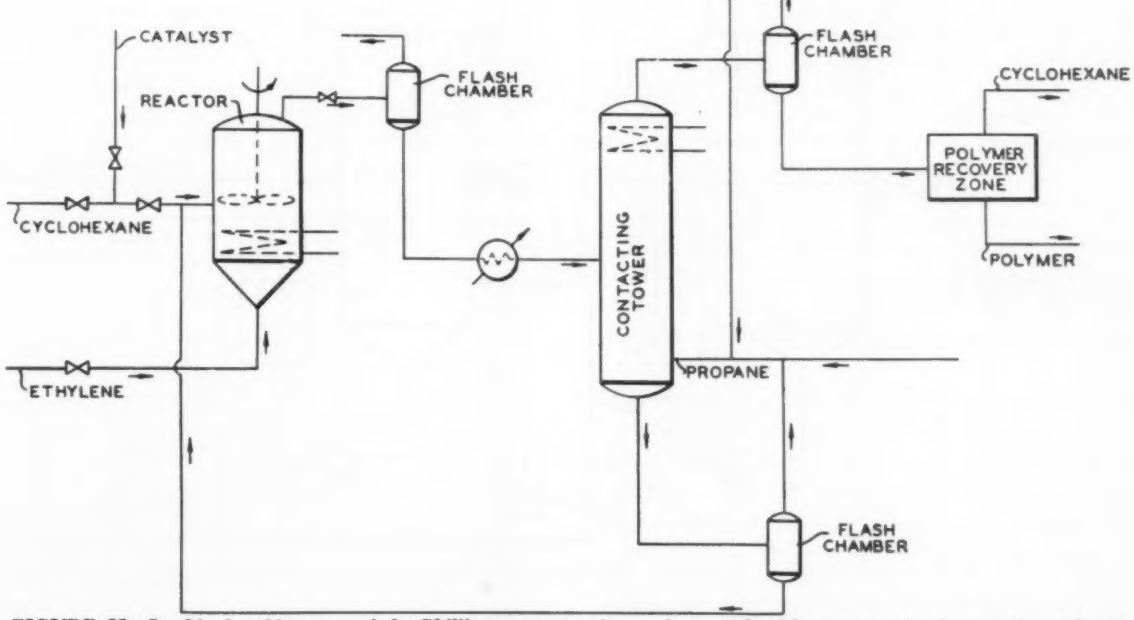

FIGURE 55—In this de-ashing step of the Phillips process, polymer is treated with propane in the reaction solvent.

thereby precipitating substantially all the solid polymer from the liquid polymer and diluent.[162] After separation in a filter or centrifuge, the liquid polymer plus solvent is flashed to recover solvent which is recycled to the reactor. It has been found[162, 206] that a portion of the liquor fed to the flashing operation is preferably returned to the reactor also. This stream, containing liquid polymer plus diluent, when fed to the reactor along with olefin and recycle solvent, effects a material reduction in the solid polymer deposit on the catalyst. Alternatively a higher olefin may be used to precondition the catalyst in this manner.[206]

It may be carried out by heating the polymer-slurry catalyst-solvent mixture to 300°-500° F. At that point a polymer-rich phase containing a major portion of the catalyst separates from a solvent-rich phase. The phases are separated; catalyst is removed from the polymer-rich phase, polymer is recovered from the polymer-rich phase, and polymer is recovered from the solvent-rich phase.[142] See Figure 54.

Alternatively, polymer of low ash content and desirable color can be recovered by treating the polymer in solution in the reaction solvent with a light hydrocarbon.[155] A catalyst-rich phase and a polymer-rich phase are recovered. This operation is carried out in a contacting tower (See Figure 55), the upper portion of which is operated at a temperature 50° F to 100° F higher than the lower portion. The untreated sample might contain 4,200 ppm of catalyst, the catalyst-rich phase from the tower bottom 13,500 ppm and the polymer-rich phase from the top of the tower only 500 ppm of catalyst.

Solvent Recovery. Foaming can be a serious problem in the evaporation of solvent from a polymer solution. Foaming does not occur however if solvent is evaporated from the solution in two or more steps.[211] In the first step, high evaporation rates are used at low polymer concentrations. In subsequent steps, higher polymer concentrations are used at considerably reduced evaporation rates to prevent foaming. As shown in Figure 56, a 1 - 4 percent solution of polymer may be fed to the first stage which is operated at 5 - 20 gal/hr/sq ft. A 7 - 8 percent solution, fed to the second stage is evaporated at the rate of 0.5 to 12 gal/hr/sq ft.

The recovery of solvent, such as cyclohexane, from vent streams in the Phillips process can be accomplished by "taking up" the solvent in granules of dry high-density polymer.[161] Thus, the product of the polymerization process finds one use in solvent recovery from the process. The mechanism of solvent removal is believed to be a combination of absorption and adsorption. See Figure 57.

Indiana Process (Group V and VI Oxides on Alumina)

The use of promoted molybdena-alumina catalysts in ethylene polymerization has been discussed by Field and Feller,[333] by Peters, Zletz and Evering,[351] by Feller and Field,[332] and by Friedlander and Oita.[335]

Catalyst Composition. A molybdena-alumina catalyst containing 8 percent molybdena on alumina is

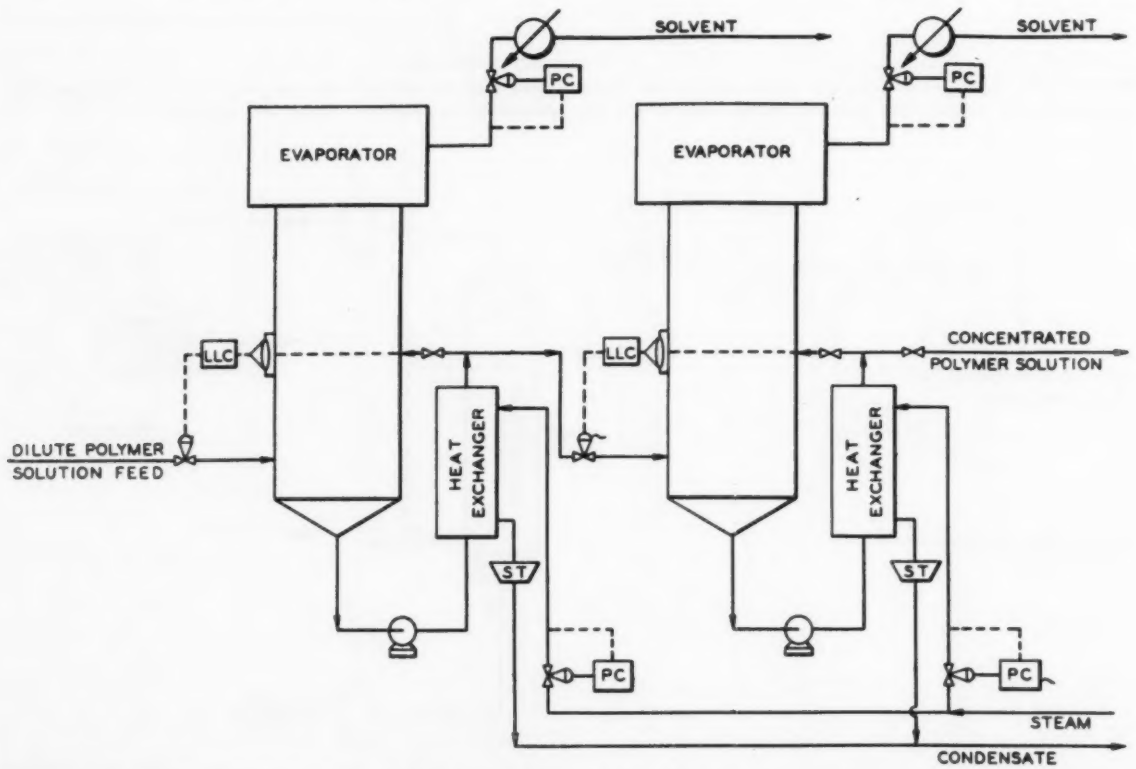

FIGURE 56—Two-step evaporation is used in recovering solvent from dilute polymer solutions in the Phillips process.

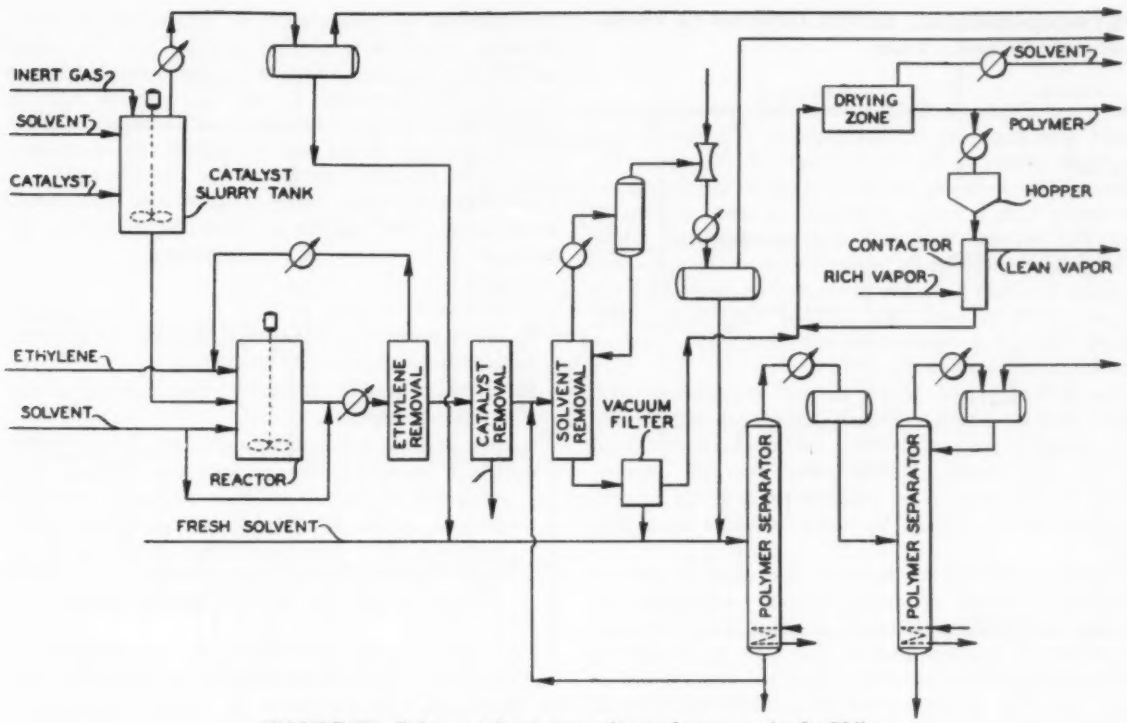

FIGURE 57—Polymer-solvent separation and recovery in the Phillips process may use dry high-density polymer as the adsorptant.

typical of those used in this process. It can be made either by impregnation or coprecipitation. In either case, preparation is continued by calcination at 500° to 600° C followed by sizing to produce 6 or 14-mesh granules or powder. A maximum dispersion of molybdena on the support, which occurs at 5 to 25 percent molybdena, gives best results in the polymerization. The molybdena-alumina catalyst is activated by heating at 430° to 480° C with hydrogen at atmospheric or elevated pressures. Although activation occurs readily at atmospheric pressure, an increase to 75 psi increased the activation rate by 40 percent; further pressure increases had no additional effect. An activation time of about 30 minutes is generally used.

The Indiana molybdena-alumina process is the subject of numerous variations in the patent literature as shown in Table 11. Thus, the original patent covered chromium, molybdenum, tungsten or uranium (Group VI_B) oxides plus alkali metal promoters[71] in an alkali metal to metal oxide ratio of 0.05 to 2.5. That same patent and other patents[118] state that vanadium, columbium, or tantalum (Group V_B) oxides may be used under essentially the same conditions. Hydrogen chloride may be used to substantially increase (double in some cases) the reaction rate for ethylene polymerization over these catalysts promoted with alkali metals. From 0.1 to 1.0 moles of hydrogen halide per mol of alkali metal give the desired effect; higher concentrations of hydrogen halide act as poisons.[89] It is claimed in an I.C.I. patent[208] that deposition of the alkali metal from the vapor phase in the formulation of such catalysts gives improved polymer yields.

TABLE 11—Combination of Reducing Materials Covered in Patents on Metal Oxide Catalysts

Oxide	Reducing Material	References
VI_B	Alkali metal	71
V_B	Alkali metal	71 and 118
VI_B	Alkali metal + HCl promoter	89
VI_B	Alkali metal hydride	91
V_B	Alkali metal hydride	116
VI_B	Alkali metal aluminum hydride	103
V_B	Alkali metal aluminum hydride	94
VI_B	Alkali metal borohydride	102
V_B	Alkali metal borohydride	112
VI_B	Alkaline earth metal	92
V_B	Alkaline earth metal	141
VI_B	Alkaline earth metal hydride	102
V_B	Alkaline earth metal hydride	112
VI_B	Alkaline earth aluminum hydride	117
V_B or VI_B	Actinide or lanthanide metal	299
V_B or VI_B	Alkali or alkaline earth metal plus $AlCl_3$	273
V_B or VI_B	Alkali or alkaline earth metal hydride + $AlCl_3$	274
V_B or VI_B	Alkali metal alkyls	194 and 240
V_B or VI_B	Aluminum halide	177
VI_B	Boron hydride or alkyl	215
V_B	Boron hydride or alkyl	209
VI_B	Aluminum alkyl	128
V_B	Aluminum alkyl	254

Subsequent patents have provided for a variety of other reducing agents in conjunction with these various heavy metal oxides. These materials include alkali metal hydrides[91] which are stated to provide a catalyst composite having the following virtues:

1. High yields of solid polymers can be obtained from ethylene
2. The catalyst can function in the presence of large proportions of liquid reaction medium
3. The catalyst has long life and retains high polymerization activity over that long life
4. Polymers having desirable ranges of physical and chemical properties can be readily produced by controlling the reaction variables.

While one might postulate that the metal hydride functions merely by reacting with catalyst poisons, that

theory is disproven by the fact that extremely pure olefin feed materials do not produce a product equal to those produced in the presence of the metal hydrides. The hydrides in fact activate molybdena to an extent that it could, if desired, be used without an extended support material (such as alumina), which is usually essential to its proper function. The quantity of metal hydride is usually between 0.01 and 0.25 parts by weight of the total solid catalyst. The use of alkali metal hydrides in conjunction with Group V_B catalysts has similarly been described.[116]

Similarly, from 0.5 to 2.0 parts of an alkaline earth metal can be employed[92] in conjunction with Group VI_B oxides to yield advantages similar to those claimed for the employment of alkali metal hydrides. The use of 0.5 to 1.0 parts of an alkaline earth metal in conjunction with a Group V_B oxide has also been covered.[14]

Alkaline earth metal hydrides are another class of materials claimed to impart similar advantages to Group VI_B oxide catalysts.[102] From 0.5 to 2.0 parts of weight of calcium hydride per part by weight of molybdena catalyst constitute a typical composition of this type. The incorporation of alkaline earth metal hydrides similarly in Group V_B oxide catalysts has also been claimed.[112]

The use of alkali metal aluminum hydrides with Group V_B oxides has also been patented.[94] From 0.05 to 0.5 parts of the aluminum hydride per part by weight of vanadia or other oxide is used. The similar incorporation of alkali metal aluminum hydrides to Group VI_B oxide catalysts has also been described.[103]

The use of alkali metal or other borohydrides in conjunction with Group V_B oxides has been described as well.[100] The borohydrides which may be employed include lithium, sodium, potassium, rubidium, cesium, magnesium, beryllium, aluminum, thorium, hafnium, zirconium, and uranium. From 0.05 to 2.0 parts of lithium or sodium borohydride, for example, are employed per part by weight of metal oxide catalyst. The use of these same borohydrides in conjunction with Group VI_B oxides[101] is claimed to give similar advantages to the four listed above.

Alkaline earth metal aluminum hydrides have been claimed as promoters for Group VI_B catalysts.[117]

Alkali or alkaline earth metals may be used together with aluminum chloride in conjunction with Group V_B or VI_B oxides.[273] Similarly, alkali hydrides or alkaline earth metal hydrides may be used together with aluminum chloride as promoters for Group V_B or VI_B oxides.[274]

Actinide or lanthanide elements, and particularly lanthanum, cerium, neodymium, thorium, uranium, and plutonium metals or their hydrides may be used to promote Group V_B or VI_B oxides on alumina.[299] In such cases, the oxides need not be pre-reduced to a lower valence state before use as polymerization catalysts.

Tennessee Eastman patents[194, 240] cover a liquid phase process operated at 90° - 200° C and superatmospheric pressure in the presence of a chromium, molybdenum or tungsten oxide supported on silica, alumina, or mixtures thereof plus a C_1 to C_{12} alkali metal alkyl promoter. Such a catalyst surprisingly can be used to polymerize C_2 to C_{10} 1-olefins whereas higher olefins can be used as "inert" solvents in processes employing similar oxide catalysts, but promoters other than the alkali metal alkyls. The Group V_B or VI_B supported oxide catalysts promoted with alkali metal alkyls are claimed to have the following advantages:

1. Increased activity
2. More polymer per pound of catalyst
3. Handles higher olefinic monomers
4. Gives crystalline polymers, particularly from higher olefins
5. Absence of low polymers and waxes
6. Much lower quantity of promoter required than when alkali metals or their hydrides employed instead of alkyls. (The former used in a 2/1 ratio to total catalyst = about 25/1 based on active catalytic oxide; this compares to a ratio of 1/1 up to 10/1 for the alkali metal alkyls.)

The heavy metal oxides may be incorporated in various forms; thus the hexavalent molybdenum can be introduced in the form of cobalt molybdate.[74] Sometimes the modifiers are introduced in greater quantities than the Group VI_B oxide, raising a question as to which is catalyst and which is modifier. Thus, calcium, strontium or barium carbides may be employed in proportions of 1 to 5 parts by weight of molybdena catalyst.[82]

Various support materials have been specified for the Group VI_B (or V_B) oxides including gamma alumina[72] and titania or zirconia.[73] Actually, the so-called "spent" molybdena-alumina catalysts from naphtha hydroforming operations are highly active catalysts for the polymerization of ethylene.[113]

Olefin Feed Composition. Oxygen is a serious poison for the molybdena-alumina catalyst; it both cuts activity and lowers specific viscosity of the polymer. Water is far less detrimental but still is undesirable and both ethylene and solvent feed must be dried in this process. Carbon dioxide and sulfur compounds are catalyst poisons and should be eliminated. However, carbon monoxide and sulfur dioxide can be tolerated,[72] and poisonous sulfur compounds are restricted to organic sulfur compounds in one patent.[82] Acetylene has a minor effect and can be tolerated; it may in fact improve separation of polymer from the catalyst, as noted above.

Operating Conditions. An increase in temperature decreased solid polyethylene yield but increased yields of semisolid polymers and oils. An increase in temperature also decreased specific viscosity of the polymer. Molybdena-alumina catalysts gave polymers of higher specific viscosity than those from nickel-charcoal catalysts, even at much higher temperatures.

Higher temperatures decreased both yield and polymer viscosity. However, as high a process temperature as possible is desirable in order to obtain maximum

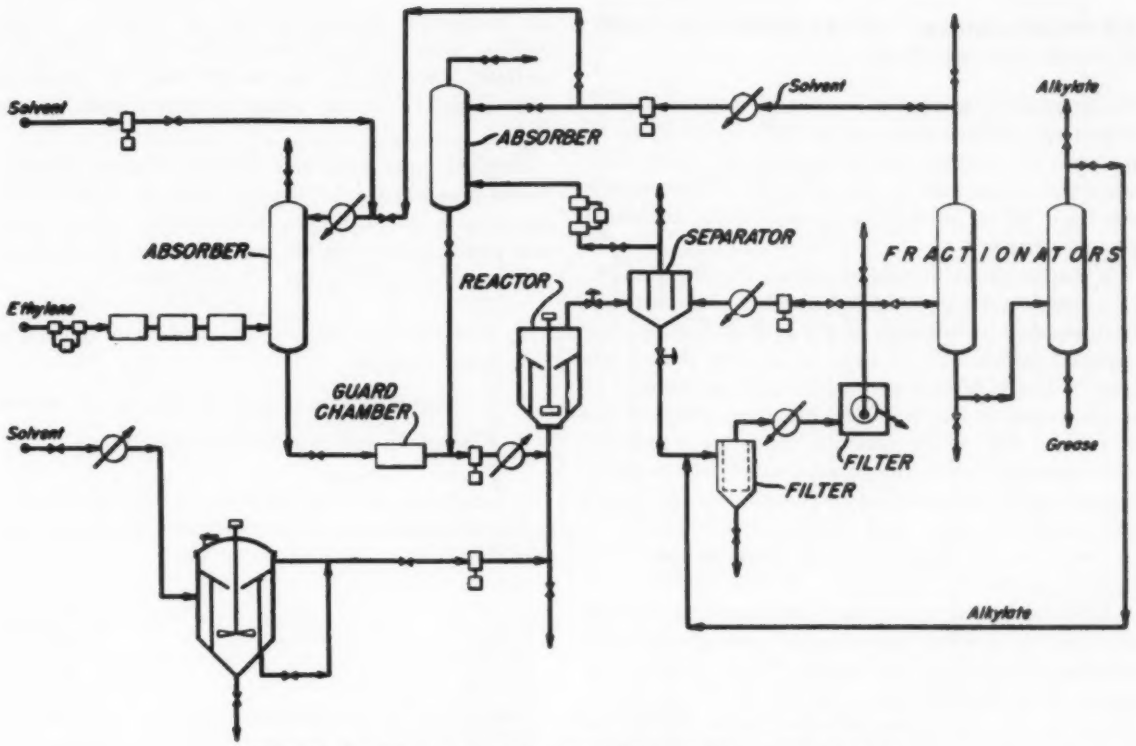

FIGURE 58—Shows the Indiana molybdena-alumina process using reactor-settlers where the catalyst is essentially handled batchwise.

solvent action and keep the catalyst free of polymer. Thus, a balance must be struck, and an optimum temperature chosen.

In mixed phase operation, pressure increased yields of polyethylene. In a flow reaction with the ethylene all in a xylene solution phase, pressure had little effect.

The flow scheme of the process is shown in Figure 58. Here reactor-settlers are employed and catalyst is essentially handled batchwise.[71]

In another version, shown in Figure 59[80] a flow reactor is used and specific provision is made for continuous catalyst reactivation.

The process is preferably carried out at temperatures of 200° to 260° C and at pressures of 500 to 1,500 psi.

It is carried out in the presence of a liquid medium which serves both as a reaction medium and as a solvent for the reaction products. Suitable media for ethylene polymerization include benzene, toluene and the xylenes. The use of such media in proportions such that dispersions containing less than 10 percent and preferably less than 5 percent of polymer issue from the reaction zone imports improvement in yield and polymer quality.[113] For propylene polymerization, the aromatics are alkylated too readily, and cyclohexane, decalin, or iso-octane are preferred solvents. Surprisingly, as discussed earlier in this survey under reaction media, higher olefins such as hexanes, octanes and decenes may also be used as reaction media.

Liquid hourly space velocities of about 2.0 are used, based on the volumes of a solution of ethylene in the liquid reaction medium. The amount of ethylene in such solutions may typically be 5 to 10 percent by weight. The solvent to catalyst ratio can be varied from 5 up to 3,000; the use of high ratios is important in obtaining high polymer yields.

In batch processes, operating periods of 1 to 4 hours are employed; the autoclave is charged with ethylene and the pressure falls as a result of the ethylene conversion reaction.

When 10 to 30 grams of resinous products per 100 grams of catalyst have accumulated, the resinous materials are extracted from the partially spent catalyst, and the catalyst can be reactivated by a hydrogen treatment similar to that used to activate the fresh catalyst.

Activation may also be carried out without added hydrogen[80] by using hydrogen containing deposits on the catalyst which are not recoverable as resins. Such a deposit is believed to be an ethylene polymer with a molecular weight from 100,000 to 400,000 and a hydrogen-to-carbon ratio of about two, indicating that the deposit is of paraffinic nature. It is claimed that catalyst that has been activated by heating in the presence of retained deposited polymer retains its activity longer than hydrogen-activated catalyst. The employment of hydrogen from an external source can be eliminated and the amount of oxidation to remove deposited hydrocarbons is less. Activation time, temperature, and pressure are essentially the same as for the hydrogen activation technique.

Essentially the same flow scheme as used for the above invention may be used in a continuous process where outside hydrogen is used in activation; a separate feature of both processes involves continuous removal of catalyst from the reaction zone, reactivation of a portion thereof with[97] or without[80] added hydrogen.

Simultaneously, a smaller amount of catalyst is withdrawn and treated with air at 550° C for 15 to 60 minutes; the oxidized catalyst is then sent to the activator and thence back to the reactor. A catalyst particle size from 100 to 200 microns is used in this continuous process scheme.

A suspension of lithium aluminum hydride, $LiAlH_4$, in a hydrocarbon provides still another medium (aside from external hydrogen or in situ hydrocarbon polymer deposits) which can be used to activate these catalysts.[112] The $LiAlH_4$ is very active and can be used at temperatures as low as 35° C, although temperatures of 100° to 300° C are generally employed in practice.

A vanadia-alumina composition which can be easily regenerated by air oxidation and which does not require any sort of activation (and which in fact is specified to be free of sorbed hydrogen) has also been covered in Indiana patents.[184]

After activation, treatment with acetylene may be employed to prevent deposition of strongly adhesive resinous products on the catalyst.[79] This involves reaction of the catalyst with from 0.01 to 5.0 percent by weight of acetylene by contacting at 20° to 325° C for 5 to 15 minutes. This acetylene treatment can be carried out in a dense phase fluid bed, following which the catalyst is transferred into an aromatic solvent medium prior to introduction of the olefin to be polymerized. Alternatively the catalyst may be contacted with acetylene during actual polymerization of the olefin.

Original work with this Indiana catalyst contemplated regeneration by burning with air followed by reactivation with hydrogen. Subsequently it was found that electropositive metals and their hydrides obviated the need for regeneration. These promoters:

1. Reduced and thereby activated both fresh and spent catalysts
2. Scavenged catalyst poisons present in the system
3. Entered directly into the catalytic process

A comparison between the products from the nickel/-carbon and molybdena-alumina catalysts indicates the following:

Catalyst	Ni/C	MoO_3/Al_2O_3
Softness	Greater	Lesser
Flexibility	"	"
Solubility	"	"
Chain branching	"	"
Density	Lesser	Greater
Crystallinity	"	"
Strength	Lesser*	Greater

* But greater than conventional high-pressure polyethylene.

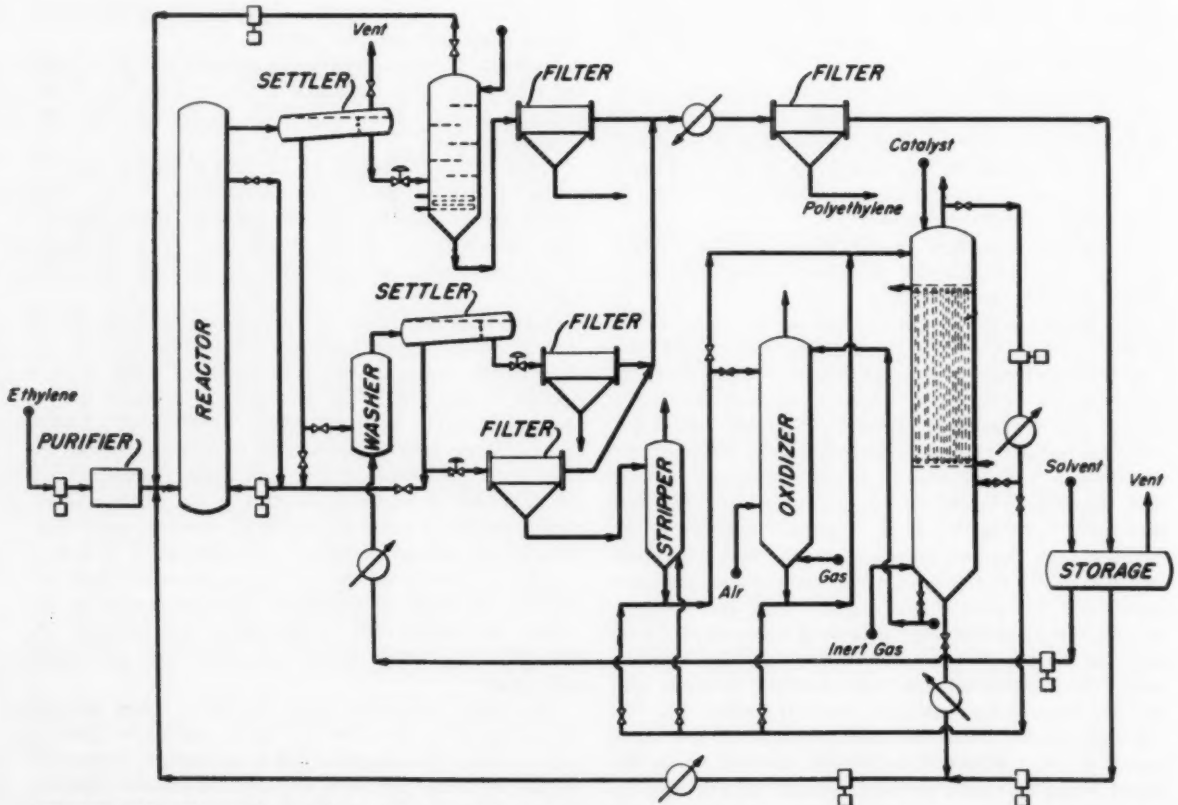

FIGURE 59—This version of the Indiana molybdena-alumina process uses a flow reactor and has provision for continuous catalyst reactivation.

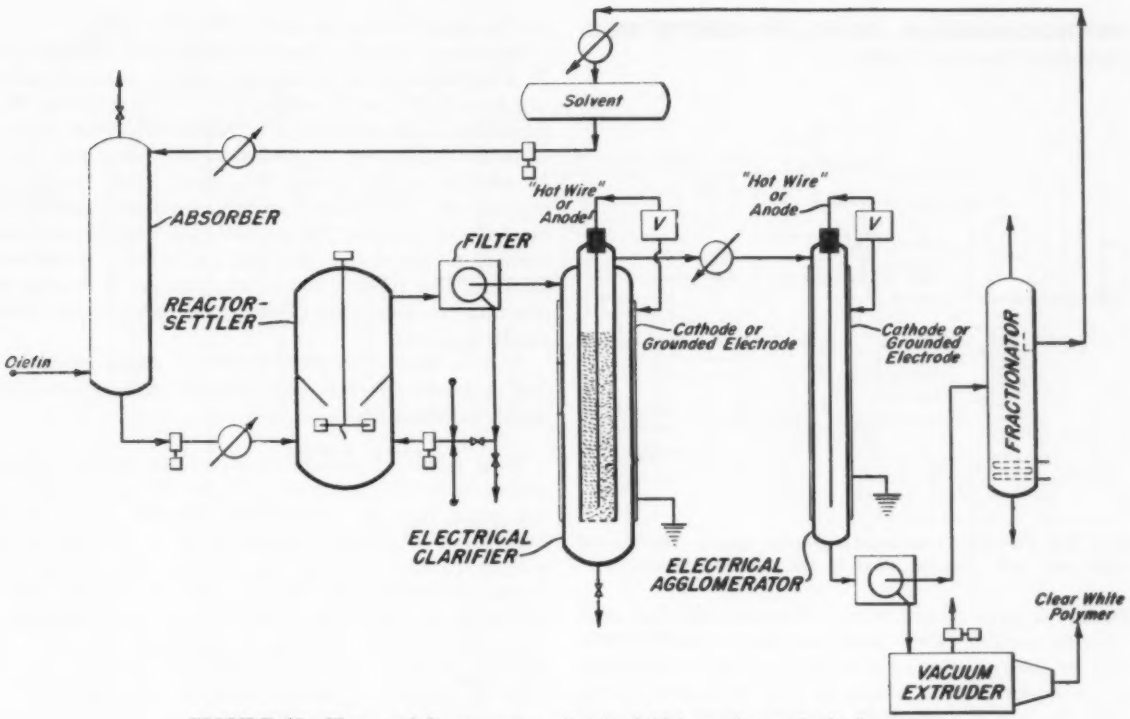

FIGURE 60—Here an inhomogeneous electric field is used to assist both separation of catalyst particles from the polymer solution and solvent from the polymer.

Polymer Recovery. The solution of solid polyethylenes or of an interpolymer of ethylene with a comonomer can be recovered by cooling the solution to 20° - 30° C and filtering the precipitated polymer. Precipitation of the solid polymer from solution can also be induced by the addition of anti-solvents such as alcohols, ketones, etc.[92]

Alternatively, the solution of solid polymer can be mixed with hot water and superheated steam to effect rapid vaporization of the solvent from the solid polymer. The aqueous slurry of polymer can be centrifuged and dried.[92]

In still another polymer recovery variation, the solution of the polymer, from which catalyst fines have been removed, can be spray dried to effect polymer recovery.[103]

The use of an inhomogeneous electric field to assist both separation of catalyst particles from the polymer solution and also solvent from the polymer has been patented.[265] See Figure 60.

Indiana Process (Nickel Oxide/Carbon plus Promoter)

A catalyst containing 0.1 to 20 percent of nickel oxide (calculated as nickel) on an activated carbon (preferably a coconut charcoal) support can have added 0.1 to 0.5 parts of an alkali metal hydride per part by weight of the supported nickel catalyst.[85] In contrast to the H_2-reduced Ni/C catalyst, this NiO/MH catalyst can employ a liquid higher olefin reaction medium. The flow scheme for this process variation is the same as for the $Mo O_3/M Al H_4$ process.[103]

Instead of an alkali metal hydride, from 0.5 to 1.0 parts of a reactive metal borohydride, such as lithium borohydride, can be used per part of nickel catalyst.[86] Sodium borohydride may also be used. The class of borohydrides specified is that which reacts with water under the polymerization conditions to yield hydrogen and includes borohydrides of sodium, potassium, lithium, magnesium, beryllium, aluminum, thorium, hafnium, zirconium and uranium.

Still another alternative involving the use of from 0.3 to 2.0 parts of an alkaline earth hydride, such as calcium hydride, can be used per part of nickel catalyst.[109] Here the nickel may be present as elemental nickel or as nickel oxide and liquid olefin reaction media may be used, unlike the case of the Ni/C catalyst in the absence of the hydride.

From 0.1 to 0.5 parts of an alkali metal aluminum hydride may similarly be used as a promoter.[183]

Calcium or other alkaline earth metal in a proportion of 0.5 to 2.0 parts by weight per part of nickel catalyst may also be used[121] at temperatures of 75° to 150° C and pressures of 1,000 psi in ethylene polymerization.

Other Metal Oxide Catalysts

Used in Conjunction with Metal Halides. Oxides of chromium, molybdenum, tungsten, vanadium, or manganese may be combined with an aluminum halide to give an ethylene polymerization catalyst.[177] It is preferred that the metal oxide be deposited on an inert carrier such as alumina or silica. Slurry operation is preferred but a fixed-bed variation may be employed. Reaction conditions are 50° to 150° C and 15 to 1,000 psig.

Mixtures of 30 - 60 percent of finely divided titanium

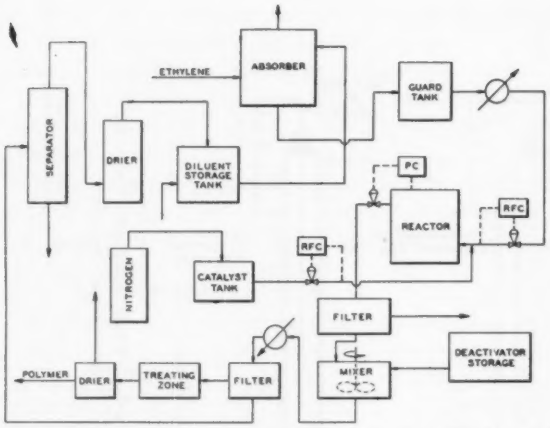

FIGURE 61—This continuous process uses a fixed metal oxide bed and a metal alkyl in the catalyst stream.

dioxide, 0.01 to 10 percent of aluminum chloride, and 1 to 40 percent of an alkali or alkaline earth metal may be used to give an effective catalyst for ethylene or propylene polymerization to hard polymers having molecular weights of 30,000 to 500,000.[176] Somewhat similarly, a mixture of titanium dioxide, aluminum halide, and aluminum metal may be used[267] as an olefin polymerization catalyst.

Used in Conjunction with Metal Alkyls or Hydrides. Titania, alumina, or zirconia constitute effective ethylene polymerization catalysts when combined with a metal alkyl, a Grignard reagent, or a metal hydride.[248] The mole ratio of activator to oxide is no smaller than one tenth in the preferred practice of this invention.

A mixed magnesium-titanium or magnesium-zirconium oxide may be used in conjunction with a lesser proportion of an aluminum alkyl at atmospheric pressure and 10° to 400° C to polymerize ethylene or propylene.[226] The olefin is passed into an organic reaction medium in which the aluminum alkyl is dissolved and the mixed oxide is suspended.

Mixtures of 1 mole of titanium dioxide with 0.1 to 5.0 moles of a mixture of diethyl aluminum chloride and ethylaluminum dichloride polymerize ethylene effectively in the presence of a hydrocarbon diluent at 200° to 350° F and 100 to 1,000 psi.[243] Such a catalyst can polymerize C_2 to C_8 olefins.

Catalysts made from titania (prepared in turn from orthotitanate esters) plus a hydrocarbon aluminum compound are useful at 140° to 150° C in propylene polymerization.[256]

A silica-alumina catalyst may be combined with 10 percent of an aluminum compound (an aluminum alkyl, an alkali aluminum alkyl, or an alkali aluminum hydride) to constitute an ethylene polymerization catalyst.[258]

Boron hydrides (particularly diborane) or lower boron alkyls may be used in conjunction with Group V_B oxides[209] or Group VI_B oxides.[215] In this composition the vanadium, niobium, or tantalum oxides are preferably supported on aluminum fluoride, AlF_3.

Aluminum alkyls of the general formula $Al R_3$ where R is hydrogen or alkyl may be used in amounts ranging from 0.001 to 20 weight percent of a Group VI_B supported oxide catalyst.[128] A particularly wide variety of mixed oxides and support materials are cited. Thus, in addition to the Group VI_B metal oxide, oxides of copper, tin, zinc, nickel, cobalt, titanium, zirconium, etc. may be present. The support may include alumina, carbon, or metal fluorides and particularly aluminum fluoride. The support may also consist of a coating of alumina on aluminum. Group V_B oxides have been similarly covered.[254]

A flow scheme employing a solid metal oxide bed and a metal alkyl in the flowing olefin solution is shown in Figure 61.[250]

Used Alone. Titanium or zirconium oxides having surface areas in the range of 50 to 500 square meters per gram may be heated with alkaline earth metal hydrides in a hydride-to-oxide ratio of 0.15 to 1.0 to give a catalyst effective in polymerizing C_2 to C_4 olefins.[291] The heating period used in catalyst preparation may vary from 1 to 20 hours. Polymerization reaction conditions include temperatures of 100° to 170° C, pressures of 300 to 3,000 psi, and the use of 10 to 25 percent of catalyst in batch operations.

A catalyst comprising zinc oxide together with silica and alumina is also effective in ethylene polymerization.[317] From 1 to 10 percent by weight of zinc oxide is used on the support which, in turn, contains 0.5 to 20 percent of alumina in the silica-alumina composite. Temperatures of 200° to 400° F and pressures of 100 to 700 psi are employed.

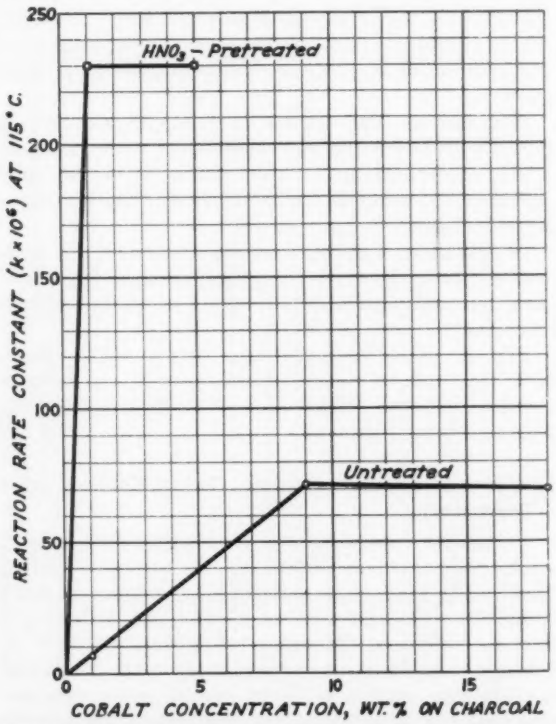

FIGURE 62—Shows how a nitric acid leach of the charcoal used in the Indiana cobalt/carbon catalyst process increases the reaction rate of the catalyst.

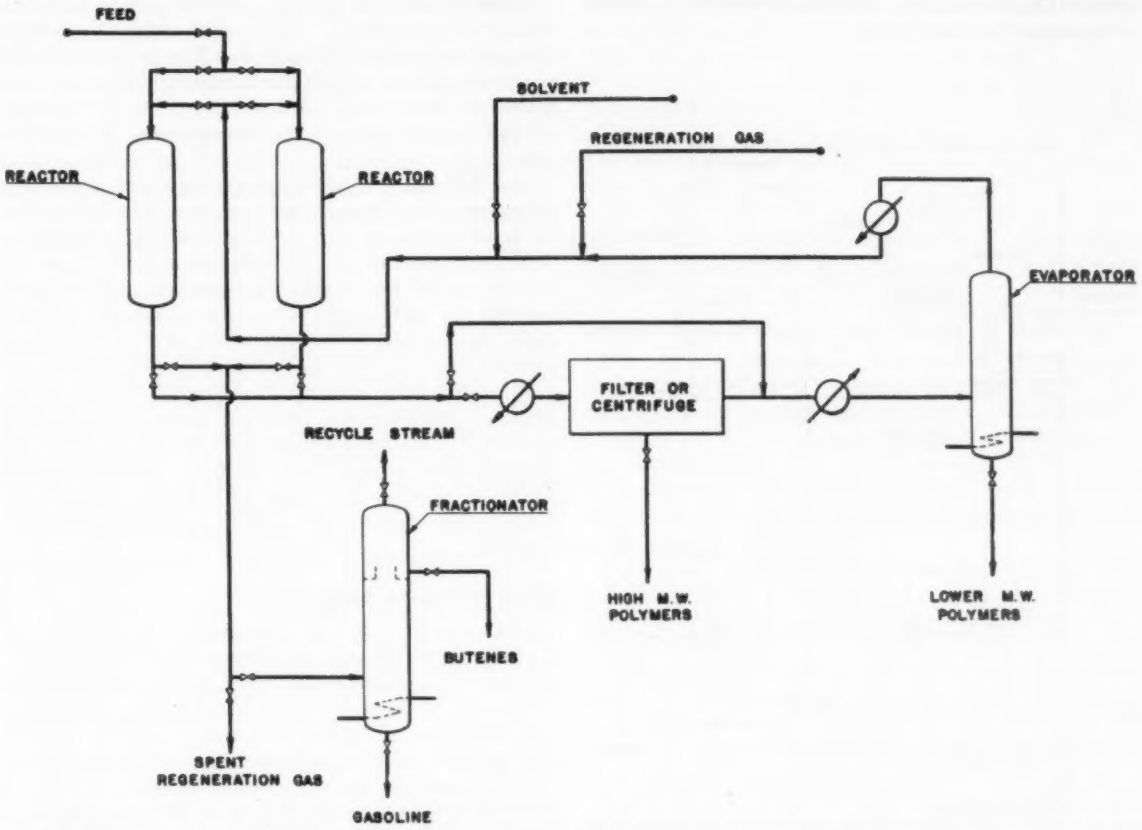

FIGURE 63—The fixed-bed Indiana nickel/carbon process in which the major product is a motor fuel component. However, the solid catalysts after use in motor fuel production, contain from 5-25 weight percent of solid ethylene polymers.

USING OTHER METALLIC CATALYSTS

Indiana Process (Nickel/Carbon)

Unreduced nickel and cobalt oxides supported on charcoal will produce dimers, trimers, and tetramers of the lower olefins as described by Cheney, McAllister, Fountain, Anderson, and Peterson[326] and also by Peters, Zletz, and Evering.[351] In contrast, the reduced counterparts of these catalysts can be used to produce linear polyethylene resins.

Catalyst Composition. A nickel-charcoal catalyst can be prepared by impregnating a charcoal support with sufficient nickel nitrate to give 5 percent nickel content. Heating to 260° C converts the nitrate to the oxide. Higher nickel concentration showed no beneficial effect. Coconut charcoal leached with nitric acid was among the best of the support materials tested by the Indiana researchers. The nitric acid leach increases reaction rate markedly as shown in Figure 62.[76] The nickel-charcoal catalyst was activated for the production of solid polyolefins by heating at 200° to 260° C with commercial hydrogen; a contact time of about 30 minutes was used in the activation step according to Peters, Zletz and Evering.[351]

Polyethylene polymer yield was unaffected by catalyst particle size but finer subdivision of the catalyst markedly increased specific viscosity of the polymer product.

Although various Group VIII metals may be used as catalysts, nickel was found to be surprisingly superior to cobalt for the production of tough, high molecular weight resinous polymers from ethylene.

Nickel-carbon catalysts may be promoted by 0.1 to 1.0 parts by weight of an alkali metal, such as sodium.[110] In such a case, and unlike unpromoted Ni/C catalysts, liquid olefin reaction media may be used.

Olefin Feed Materials. Carbon monoxide, hydrogen sulfide, and ammonia are poisons for these nickel/carbon and cobalt/carbon catalysts. Oxygen in amounts from 1,000 to 2,000 ppm (0.1 to 0.2 percent) did not have a harmful effect (in contrast to the quite harmful effects of such concentrations on the peroxide-catalyzed polymerization of ethylene). The presence of acetylene in amounts greater than trace quantities is undesirable also.

Fixed-Bed Operation. A fixed-bed vapor-phase operation using the nickel/carbon or cobalt/carbon catalyst has been described.[65] In this particular process variation, shown in Figure 63, the major product is a motor fuel component but the solid catalysts after use in motor fuel production contain from 5 to 25 weight percent of solid ethylene polymers. These resins are removed from the catalyst bed by alternate extraction of twin reactors with suitable solvents. Operating temperatures from 100° to 150° C and operating pressures

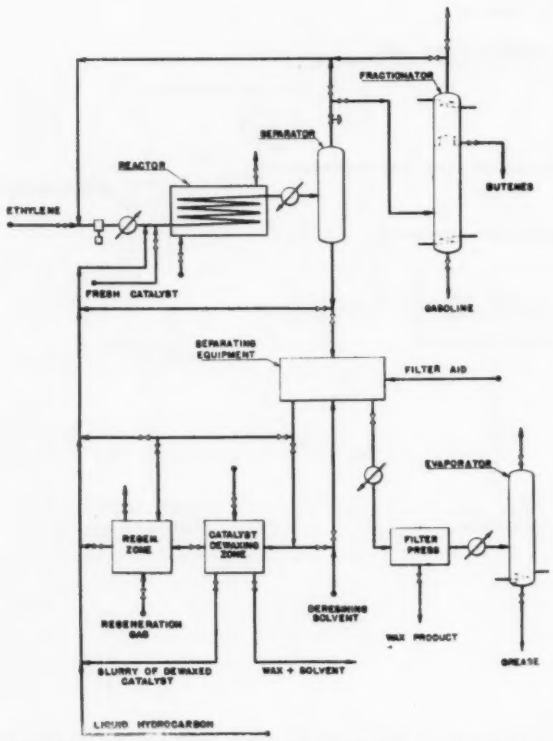

FIGURE 64—This version of the Indiana nickel/carbon process uses powdered catalyst, solvent and olefin as a slurry in a pipeline reactor.

from 2,000 to 5,000 pounds are preferred. Yields of solid rather than liquid polymers were increased by using nickel/carbon rather than cobalt/carbon catalysts and by using low catalyst concentrations on the active carbon, high pressures, and low temperatures. Interestingly, the same catalytic metals on alumina or silica supports formed almost no solid polymers.

A similar metallic catalyst patented in 1954 by Monsanto[66] involved nickel or cobalt on a diatomaceous earth support. In addition from 0.01 to 10 parts of a promoter metal (such as copper, cerium or thorium) was to be present. The process was to be carried out at 200° to 300° C and at 500 to 3,000 atmospheres in the presence of 0.001 to 0.2 moles of carbon monoxide and 0.001 to 0.6 moles of hydrogen per mole of ethylene. Polymers with molecular weights from 15,000 to 40,000 are produced; these polymers are claimed to be more stable to heat, light, and oxidation than polymers made by conventional methods. The oxygen content of the ethylene feed is to be below 0.06 percent.

A liquid phase process using the Indiana Ni/C catalyst (as contrasted to the vapor phase process[65] and the solution slurry process[75]) has been described[93] using a Ni/C catalyst which is ground, mixed with an inert porous filler (such as silica, alumina, zirconia, kieselguhr, etc.) and pelleted. The supported catalyst composition preferably contains 5 to 25 percent by weight of the metal/carbon catalyst.

Slurry Operation. A slurry catalyst process in which powdered catalyst, solvent and olefin are passed through a pipeline reactor.[75] See Figure 64. A stirred autoclave and an alkylation contactor were also suggested as alternative reactor designs for the conduct of this process, as was the Hengstebeck reactor design.[42]

It is interesting to note that aliphatic olefins or olefin polymers are not suitable solvents since they lead to low or trace yields of high molecular weight polyolefins. This is in contrast to the molybdena catalyst process where olefins are acceptable solvents. The desired solvents for this nickel/carbon process are the alkanes, cyclo-alkanes and aromatics which are the preferred solvents in most olefin polymerization processes.

A weight space velocity in the range of 0.01 to 5.0 grams of ethylene per hour per gram of catalyst is employed. The polymer products of this process are predominantly grease-like to solid polymers having molecular weights from 300 to 25,000 or more; relatively minor amounts of gasoline-range products are produced.

Using Grignard Reagents

The polymerization of ethylene can be carried out in the presence of reagents yielding Grignard-type compounds. Thus, from 0.005 to 5 percent of materials comprising at least 0.002 percent magnesium or zinc and 0.003 percent of an alkyl halide may be charged into an inert medium such as isooctane, diethyl ether, benzene, and the like. Operation at 100° to 250° C and ethylene pressures of 400 to 1,500 atmospheres is claimed to give a high-strength polyethylene of high molecular weight. The oxygen content of the ethylene should be held below 10 ppm.[38]

Mixtures of Grignard reagents with a silver halide such as silver chloride or silver fluoride constitute a useful ethylene polymerization catalyst.[197] Pressures of 1 to 200 atmospheres and temperatures of 0° to 300° C are used. The ratio of Grignard reagent to silver halide is at least two to one.

Mixtures of Grignard reagents with either aluminum chloride or aluminum ethoxide give catalysts which are operable in ethylene polymerization at 150° to 250° C and at moderately high pressures of 10 to 500 atmospheres.[222]

Using Alfin Catalysts

The use of mixtures of the reaction products of sodium and *al*cohols plus sodium with ole*fins* gives the ternary alkyl-alkoxide-NaCl mixture known as the Alfin catalyst as developed by Prof. A. A. Morton at M.I.T.

The use of this catalyst in ethylene polymerization has been described.[61] Operation at or below the critical temperatures and at pressures at or below the critical pressure are specified. These conditions are 9° C and 55 atmospheres for ethylene. The reactive nature of the catalyst requires that water and oxygen must be rigidly excluded. Hydrocarbon solvents such as pentane may be used and such solvents may permit higher operating temperatures than 9° C because ethylene can be kept in solution at such higher temperatures under 55 atmospheres pressure. The amount of solvent should be at least equal in volume to the ethylene present and

preferably more, even up to ten times that amount. The quantity of catalyst may vary from 0.001 to 5.0 parts per 100 parts of ethylene. Efforts in some laboratories to duplicate this work have been successful, however.

The use of ethers, acetals, or amines in place of hydrocarbon solvents is claimed to be advantageous[148] when using Alfin catalyst systems. A wider variety of monomers can be used when employing the improved solvents, according to the inventor.

Using Friedel-Crafts Catalysts

Propylene and 1- and 2-butene can presumably be polymerized to solid polymers by using strong solutions of a Friedel-Crafts type catalyst in alkyl halide solutions according to an early patent.[9] Greater than 25 percent of such a solution containing greater than 2 percent solvent is employed, based on the olefin to be polymerized, at temperatures below —10° C. Recent work casts doubt on the validity of these claims.

Antimony pentafluoride, SbF_5, may be used to polymerize propylene to oily to resinous products. From 0.1 to 3.0 percent of catalyst may be used and halogenated solvents, such as methyl chloride or ethylidene difluoride are preferred. The reaction may be carried out at 0° to —165° C.[104] This patent goes on to point out some interesting differences in reactivity of metal halides as olefin polymerization catalysts:

Element	Chloride	Fluoride
Antimony	Inactive	Active
Aluminum	Active	Inactive
Titanium	Active	Inactive
Zirconium	Active	Inactive
Boron	Inactive	Active

A major amount of technical-grade aluminum chloride may be combined with a minor amount of a lead or tin tetraalkyl to give an ethylene polymerization catalyst[219] which can be used at 60° - 80° C and 10 to 100 psi. A similar combination promoted with minor amounts (0.0055 moles per mol of aluminum chloride) of vanadium or titanium has also been patented.[229] It is pointed out in the latter patent that commercial aluminum chloride may already contain these activator materials.

Using Boron Compounds

From 0.1 to 20 percent of a boron hydride based on the weight of ethylene may be used as a polymer catalyst.[68] Diborane, B_2H_6, is the preferred boron hydride but its homologs as high as $B_{10}H_{14}$ may be used. A contact time of 20 hours at a reaction temperature of 55° C and pressures from 1,200 to 4,500 psi was specified. The freedom of the catalyst from oxygen gives a polymer which is free from oxygen-bearing fragments (as might be produced when peroxide catalysts are used) and which is therefore more stable, it is claimed.

From 1 to 8 parts of diborane or an alkyl or aryl boron compound per part of titanium tetrachloride or other Group IV to VIII salt constitute an effective catalyst.[147] From 0.1 to 5.0 percent of catalyst is used based on the weight of the monomer. Temperatures of 50° to 200° C and pressures of 50 to 2,000 psi are employed. Inert liquid reaction media such as aliphatic hydrocarbons, aromatic hydrocarbons, ethers, olefins having non-terminal double bonds. cycloolefins, chloroaromatics or perfluorocarbons may be used.

The use of boron trichloride in the presence of an electrodeless discharge can effect the polymerization of ethylene at ordinary temperatures and pressures.[139] The electrodeless discharge is in the low frequency range below 10 kilocycles.

The combination of boron trifluoride with ferric pyrophosphate hydrate is effective[310] in polymerizing ethylene at —20° to 100° C in the presence of liquid hexane as a solvent.

Using Alkali Metals, Their Alkyls or Hydrides

The alkali metals may be used as reducing agents in conjunction with metal oxides as discussed in the preceding text to produce effective olefin polymerization catalysts. In that function, they may be employed as the element, the hydride or the metal alkyl. Similarly, some of these alkali metal substances, and particularly lithium and its derivatives, may be employed as polyolefin catalysts themselves.

The alkali metal may be used in the form of a solution of the metal organic. Thus, alkyl and aryl lithium compounds can be used to polymerize ethylene.[7] Low catalyst concentrations, ranging from 0.01 to 0.1 percent based on the monomer were used. Temperatures of 50° - 150° C and pressures of about 1,000 atmospheres were used for reaction times of 16 to 17 hours. The purity of the ethylene fed to this catalyst is stated to be of critical importance, particularly with respect to oxygen content which must be kept below 1,000 ppm and preferably below 500 ppm.

Lithium hydride supported an inert adsorbent porous solid material (alumina, activated carbon, sodium chloride, etc.) may be used at 125° to 250° C and about 500 psi to polymerize ethylene.[135] Alternatively, unsupported lithium hydride may be used at 190° to 300° C.

Sodium hydride or potassium hydride supported on alumina may be used at 125° - 175° C and 15 to 1,500 psi to polymerize ethylene.[257]

Lithium metal dispersions in hydrocarbon media or "high surface" lithium on inert supporting materials may be used as ethylene polymerization catalysts.[165] From 5 to 25 weight percent of lithium may be used based on ethylene.

Sodium metal supported on an alumina adsorbent material may be used as a catalyst to produce solid polyethylene.[195] The nature of the support was found to be particularly critical; surface areas of 150 to 300 square meters per gram and an average pore radius at 25 Angstroms are desirable. Lower or higher surface area materials were ineffective, as were charcoal, silica, titania, or zirconia gels. From 5 to 25 percent of sodium may be used per weight of ethylene. Higher olefins may be employed as solvents, as may a variety of aliphatic or cycloaliphatic hydrocarbons.

The combination of lithium aluminum hydride with boron trifluoride or boron trichloride in an aluminum to boron ratio from 2 to 5 has been patented[140] as an improved olefin polymerization catalyst. The conditions under which it is to be used include temperature of 125° to 175° C and pressures of 20 to 120 atmospheres in the presence of an inert liquid medium, which may

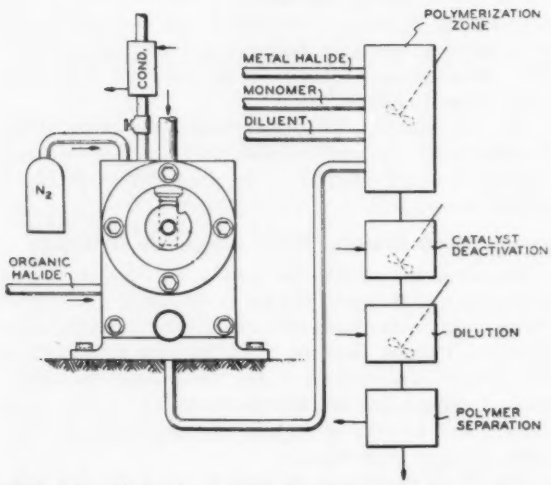

FIGURE 65—In this mechanical activation reactor, magnesium or aluminum may be cut so that a fresh metallic surface is exposed to an alkyl halide prior to or during contact with a titanium halide plus a monomer and a diluent.

be a saturated hydrocarbon, an aromatic hydrocarbon, or an ether.

Using Transition Metal Hydrides

Titanium, zirconium, or hafnium hydrides in finely divided form and in the presence of added hydrogen halide are effective in the polymerization of propylene.[261] From 1 to 20 percent of such a catalyst, based on propylene, are used in polymerization at 20° to 60° C.

The combination of titanium hydride with an alkyl aluminum halide also constitutes a useful catalyst for ethylene polymerization.[293]

Using Other Metals and Their Compounds

Magnesium or aluminum may be cut so that a fresh metallic surface is exposed to an alkyl halide prior to or during contact with a titanium, vanadium, or zirconium halide plus a monomer and a diluent.[225] See Figure 65.

Magnesium, and the members of Group II_B of the periodic table, namely zinc, cadmium, and mercury may be used in conjunction with organic peroxides in the presence of saturated hydrocarbon diluents to produce wax-like polyethylenes.[30] Tertiary butyl perbenzoate was a typical peroxide used at 115° C and a pressure of 30 to 100 atmospheres. From 0.1 to 4.0 percent of catalyst was used at liquid hourly space velocities of 0.1 to 10.0 giving contact times from 3 minutes to 6 hours.

Calcium, or other Group II metals including barium, magnesium, zinc, and cadmium may be used to polymerize ethylene to waxy polymers.[35] The oxygen content of the ethylene is preferably held below 10 ppm; pure catalytic metals are used, with copper being excluded in particular because of a poisoning effect on the reaction. From 0.005 to 5 percent of the catalyst is used at 200° to 275° C and 700 to 1,500 atmospheres. Hydrocarbons, ethers, or liquid ammonia are useful reaction media for this process.

Alkaline earth metal hydrides may be supported on activated carbon to give an ethylene polymerization catalyst.[307] From 0.1 to 15.0 gram atoms of carbon are employed per mole of alkaline earth metal hydride and these components are heated together in an inert atmosphere to an activation temperature between 400° and 700° C for at least two hours.

Calcium, strontium, and barium carbides are the major ingredients along with Group VI_B (chromium, molybdenum, tungsten or uranium) oxides as a minor ingredients are claimed in one variation of the Indiana process as discussed earlier.[82]

Complex mixtures containing the following

a. A titanium, zirconium, hafnium or germanium halide
b. A Group I or Group II carbide or acetylide (0.5 to 10.0 moles per mole of metal halide)
c. An organometal halide, a complex (e.g. alkali aluminum) hydride, or an organic halide plus a metal (0.2 to 3.0 moles per mol of metal halide)

can be used to give high molecular weight polymers which can be produced at exceptionally low temperatures and pressures. However, preferred operating conditions are 50° to 300° F and 100 to 700 psig. Reaction time may vary from one second to an hour or more.[134] A similar complex mixture incorporating, instead, 0.2 to 3.0 moles per mole of metal halide of an organophosphorous compound of the formula R_3P as component (b) has also been patented.[137]

A reduced phosphomolybdic acid of the general formula $P_2\,Mo_{22-24}O_{20-42}$ may be used as an ethylene polymerization catalyst[157] for use at 80° to 225° C and 400 to 2,500 psi.

Finely divided vanadium, niobium, or tantalum may be used to polymerize ethylene at 20° - 60° C and atmospheric pressure.[202] Similarly, finely divided thorium or uranium may be used, alone, or in the presence of halogen-containing activators (such as hydrogen halides.[203] Finely-divided rare earth metals are described as catalysts in still another patent.[204] Hydrides of Group IV_B, V_B, VI_B or VIII metals which are performed or formed in situ from the metals and hydrogen may also be used.[205] The advantages claimed for these systems are:

a. Absence of halogen eliminates corrosion of molds in processing the resultant polymer
b. The use of hazardous aluminum alkyls is avoided
c. Better control is achieved with a one-component catalyst
d. Less equipment is required
e. There is less need for blanketing with inert gases.

Copper, silver, or mercury acetylides may be used to polymerize gaseous olefins at temperatures above the decomposition temperatures of the acetylides and at pressures of 10 to 1,000 psi.[199] From 0.001 to 1.0 percent of catalyst is used based on the olefin present; the molecular weight of the polymer produced varies inversely with the proportion of catalyst, giving a good means of molecular weight control.

From 0.01 to 5 percent of titanous ion plus 0.001 to 5 percent of a hydroxylamino compound based on the weight of polymerizable monomer may be used in a catalyst combination effective in producing a rapid reaction at low (near O°C) temperatures[51]. Vanadous ion in conjunction with a hydroxylamine salt is covered in a similar patent.[67] The use of titanium tetrachloride together with a C_1 to C_4 aliphatic azo compound produces a complex reaction product, stable below —10° C, which is an active ethylene polymerization catalyst.[262]

The combination of molybdenum pentachloride or hexafluoride with an oxide, halide, or salt of molybdenum, tungsten, vanadium, or chromium (where the valence of the metal in the second material is four or less) constitutes an effective ethylene polymerization catalyst for use at 25° to 250° C and 3 to 300 atmospheres.[196] A similar catalyst composition which has been patented[201] is a mixture of a molybdenum pentahalide or hexahalide with a titanium or zirconium halide, the latter containing metals having a valence of four or less.

Titanium tetrachloride together with activated carbon dispersed in an inert liquid medium constitute an active catalyst for the polymerization of C_2 to C_8 alpha-olefins.[289] The preferred activated carbon for use in this process is one prepared by the thermal decomposition of aluminum carbide, although other activated carbons may be used.

The combination of pyrophoric iron with oxygen catalizes the preparation of polyethylene, polypropylene, or ethylene-propylene copolymers.[311] Pyrophoric iron may be maintained in suspension in a stirred hydrocarbon medium and ethylene containing a minor proportion of oxygen bubbled into the medium at 50° to 300° C.

Polymer Properties

THE PROOF OF THE POLYMER is in the properties. Aside from convenience, economy, or safety of manufacture, most of the processes and process variations described in this review up to this point have had one goal in mind—the production of polymers of superior properties and hence of superior marketability.

Properties of some typical polymers are shown in Table 12.

TABLE 12—Comparison of Properties of Polyethylenes made by Different Processes

Product	High-Pressure Polymer	Phillips Co-polymer	Ziegler Polymer	Indiana Polymer	Phillips Polymer
Crystallinity %	65	75	85	87	95
Relative rigidity	1	2	3	4	4
Softening temp., °F	220	245	255	255	260
Tensile strength	2000	2500	4000	.....	5500
Elongation	500	300	100	.....	20
Impact Strength	10	5	4	.....	3
Density	0.920	0.935	0.950	0.960	0.965

One of the first correlations between polymer structure and physical properties was that made by Richards[354] on the basis of the original I.C.I. high pressure polyethylenes. Later, Jones and Boeke[344] made a correlation with emphasis on Phillips type linear polyethylenes. Most recently a very comprehensive correlation including a wide variety of polyolefins has been published by McGrew.[348] Quantitive relationships between the physical properties of polyethylenes have been worked out by Sperati, Franta, and Starkweather.[337]

Generally speaking, the physical properties of polyolefins are functions of

1. Molecular weight
2. Molecular weight distribution
3. Degree of crystallinity (in turn related to degree and type of chain branching)
4. Arrangement of crystalline and amorphorous regions in the solid (texture)
5. Presence of oxygen-containing groups or unsaturation

These structural variations are reflected in density, melting point, and mechanical properties.

DENSITY

Density is closely related to crystallinity. However density is a gross concept which is easily measured. Characterization of polyolefins as low-density or high-density materials is common.

High density, or high percentage of crystallinity, primarily effects improvement in those polymer properties which are concerned with slight movements of polymer segments with respect to one another (in contrast to extensive movements or rupture). These properties include

1. Crystalline melting point
2. Young's modulus in tension
3. Bending modulus (related to stiffness)
4. Yield point (related to the tension necessary in cold drawing)
5. Surface hardness
6. Permeability to water vapor
7. Sorption of gases and liquids
8. Transparency

—in other words, the mechanical properties normally encountered in using polyolefin resins.

Density must be controlled to give maximum product utility. Extreme variations have the following effects on product properties:

Product	Too low density	Too high density
Film	Too limp	Too stiff
Molding	Not stiff	Too stiff (brittle)
Monofilaments	Too much shrinkage	Too stiff (harsh fabric)

As pointed out by McGrew,[348] density is a prime criterion in the evaluation of polyethylene plastics because:

1. Density is related to stiffness almost linearly
2. Density is a fairly good measure of temperature resistance
3. Density can be correlated reasonably well with abrasion resistance
4. Density is often the most useful indicator of permeability to solvents and oils.

Materials which do not have an extremely high degree of crystallinity (or high density) are more trans-

parent. Thus, polypropylene is generally more transparent than polyethylene because the crystallinity of polypropylene is considerably less than that of polyethylene. Typical crystallinity values might be 60 percent for polypropylene vs. 95 percent for polyethylene.

Density measurements are usually made on specially molded and annealed samples.[344] The technique involves flotation in a liquid as described by Hunter and Oakes.[343] The density-gradient technique for measurement of plastics density bears ASTM Designation D1505-57T.[319]

CRYSTALLINITY

As mentioned earlier, the trend in polyolefin manufacture has been to higher density polymers. Density varies as the ratio of crystalline to amorphous polymer. Crystallinity in turn is a function of:

1. Molecular weight (long chains entangle more easily)
2. Molecular weight distribution
3. Chain branching
4. Degree of stereospecificity

if one assumes one standard fabrication history (time, temperature and pressure used in fabrication) for a group of polymers being compared. Of these, the degree of short chain branching or non-linearity in polyethylene is by far most important, while in polypropylene, the degree of stereospecificity is most important.

A complete study of crystallinity in polyolefins involves the following:

1. Crystal structure of the unit cell. This is a question of the precise arrangement of the atoms in the polymer crystal.
2. Percentage crystallizability. This is the weight percent of ordered material as opposed to the weight percent of disordered, or amorphous, polymer. The extent to which this ability to crystallize manifests itself in crystallinity is in turn a function of cooling rate, annealing, etc.
3. Size and shape of crystallites. The polyolefin crystals tend to mass in spherical clusters of radiating needles called spherulites.

Methods that have been used for the determination of polyolefin resin crystallinity include:

a. X-ray diffraction
b. Density
c. Determinations of heat content
d. Infrared absorption
e. Nuclear magnetic resonance

As mentioned above, chain branching is the main determinant of degree of crystallinity in polyethylene. However, a distinction must be drawn between

- **short chain branching,** which is probably the product of intramolecular chain transfer giving first transient cycloparaffin structures of 4 or 5 carbon atoms and then short branched chains. The degree of short-chain branching is determined by the measuring of the infrared absorption peak characteristic of the methyl group. Such branching is absent in polymethylene chains prepared by decomposition of diazomethane and is nearly absent in the newer stereo-specific polymers. It is, however, present to a considerable degree in the early high-pressure polyethylenes. See Table 13.
- **long chain branching,** which is probably the product of intermolecular chain transfer. A consequence of long-chain branching is wider molecular weight distribution which is discussed in the paragraphs which follow.

TABLE 13—Methyl Groups per 1000 Carbon Atoms of Various Polymers

Polymer	Total methyl groups	% Terminal methyl	% Side Chain methyl	% Side Chain ethyl
Polymethylene	<1.5	.....	.....	.....
High-pressure polyethylene	20–25	25	5	70
Ziegler polyethylene	3–5	80	.....	20
Phillips polyethylene	<1.5	.....	.....	.....
Ethylene-propylene copolymer (Phillips)	25	20	80	.....
Ethylene-butylene copolymer (Phillips)	15	10	.....	90
Natta polypropylene	330	5	95	.....

SOFTENING OR MELTING POINT

The rise in softening point of polyolefin resins has been one of chief benefits of the development of new processes in recent years; it permits production of molded products stable at boiling water temperature, etc. The softening point of polyethylene is almost independent of average molecular weight and molecular weight distribution. Softening point is primarily a function of crystallinity and hence of polymer structure.

Softening and melting points are essentially synonymous in highly-crystalline polymers.[210] The Vicat softening temperature (ASTM D1525-58T) is that temperature to which the polymer must be heated to allow a needle 1 sq. mm. in area to penetrate one mm. under a load of 1 kilogram.[37]

A tabulation showing some relations between the types of unsaturation in the polymer structure and flow properties of the polymer are given in Table 14. It will be noted that internal-cis and side chain vinyl groups are missing from these polymers. The nature and content of unsaturation in a polyolefin is also of interest in determining the polymerization mechanism, particularly the termination step.

The term crystalline melting point is also used. This is the temperature at which all crystallinity disappears from the sample and it appears clear when viewed through crossed Nicol prisms in a hot-stage microscope.

MOLECULAR WEIGHT

Molecular weight and molecular weight distribution affect primarily polymer properties such as

- melt viscosity
- tensile strength
- low-temperature brittle point
- tear resistance

because these properties involve either extensive movements of polymer segments or rupture of the entire sample. Thus, looking at it in another way, behavior of a polymer under increased mechanical loads and flow properties at elevated temperatures (including processability in various operations such as injection molding or extrusion) are those properties primarily influenced by molecular weight.

Weight average molecular weight is generally meas-

TABLE 14—Relation of Unsaturation to Flow Properties of Various Polyethylenes

Process	Polymer Properties			Polymer Unsaturation			
	Inherent Viscosity	Density	Softening Pt., °C (30° bend)	Terminal vinyl RCH:CH_2	Internal trans RCH:CHR'	Methylene (Side chain vinylidene) RRC:CH_2	Total/1000 C's
High pressure	0.9	0.92	90	18%	16%	66%	0.45
Phillips (slurry)	2.0	0.96	125	95%	3%	2%	1.95
Phillips (fixed-bed)	.....	.....	.....	7%	92%	1%	4.8
Ziegler original	2.3	0.95	110	35%	35%	30%	0.82
Ziegler development	3.6	0.96	120	73%	4%	23%	0.22
Indiana MoO_2 /Al_2O_3	.....	0.96	.....	.....	70%	30%	.....
Indiana Ni/C	.....	0.95	.....	4%	48%	48%	.....

ured by solution viscosity—a relative method which is in turn calibrated by an absolute method such as light scattering as described by Flory.[334]

Number average molecular weight is usually obtained from some colligative property such as osmotic pressure or freezing point depression.

Molecular weight must be carefully controlled. Excessive variations adversely affect product properties as follows:

Product	Too low mole. wt.	Too high mole. wt.
Film	Too weak	Extrudes too slowly
Molding	Not tough enough	Not moldable
Monofilment	Too low tenacity	Too hard to extrude fast

Solution Viscosity

Staudinger in 1934 first found that polymer molecular weights could be related to the viscosities of dilute solutions of those polymers in tetralin measured at 75°C. Since that time a number of solution viscosity terms have been used. Such terms have been based on measurements of 0.1 to 0.5 percent solutions in toluene or xylene at 85°C, decalin at 135°C and even in chloroform at 25°C. These are defined as follows:

1. Relative viscosity $= \frac{\text{viscosity of the polymer solution}}{\text{viscosity of the solvent}}$
   This is a number greater than 1.0.
2. Specific viscosity = relative viscosity — 1. This term has been used in Standard Oil Co. (Indiana) patents.[71] Typical specific viscosity ranges for usable polymers are from 0.01 to 6.0.[80, 97, 103]
3. Reduced specific viscosity $= \frac{\text{specific viscosity}}{\text{conc. in gm/100 cc.}}$
   This term is used by Hercules, for example.[203]
4. Inherent viscosity $= \ln \frac{\text{relative viscosity}}{\text{conc. in gm/100 cc.}}$
   A value of 3.0 is equivalent to a molecular weight of 100,000 for polypropylene.[186]
   Inherent viscosities may run from 0.5 to 5.0[129] for high density polyethylene.
5. Reduced viscosity $= \frac{\text{viscosity of the solution}}{\text{conc. in gm/100 cc.}}$
6. Intrinsic viscosity = inherent viscosity extrapolated to zero polymer concentration.

Numerical relationships between intrinsic viscosity and molecular weight have been developed by Kemp and Peters[345] and by Harris.[339]

Melt Viscosity

Melt viscosity in poises can be determined by the method of Dienes and Klemm.[331]

Melt viscosities of about 10^7 to 10^8 poises correspond to molecular weights of 50,000 to 75,000 for polyethylene; this is the top of the range which can be processed on polyethylene extrusion machinery without extensive modifications. A usual produce range is 2×10^5 to 5×10^6 poises.[103]

Melt viscosity is a function of both weight average molecular weight and molecular weight distribution.

Melt Index

Melt index is related to average molecular weight and is also a rough measure of the rate of polymer flow in thermoplastic processing equipment. For a given catalyst and monomer, melt index and inherent viscosity are related nearly linearly. Melt index is determined by ASTM Method D-1238-57T.

Melt index is an empirical measure of flow properties of the polymer. It has long been used in the characterization and grading of polyethylenes. In fact, it is sometimes called grade number, rather than melt index. Melt index is expressed in decigrams per minute.[260]

MOLECULAR WEIGHT DISTRIBUTION

Molecular weight distribution along with molecular weight and crystallinity are the three principal structural parameters affecting polyolefin properties. Relatively narrow distribution is believed to be advantageous and to produce particularly tough polymers. The toughness of polymers of the same melt flow will increase as the molecular weight distribution is narrowed. Various measurements of molecular weight distribution have been developed[325] such as

a. fractionation
b. ratio of weight average molecular weight to number average molecular weight as described by Herdan[340]
c. measurement of melt elasticity

As pointed out above, long-chain branching (which is associated with intermolecular chain transfer) is the primary cause of wide molecular weight distribution.

A narrow molecular weight distribution is produced by replacing halogen with alkoxy or aryloxy groups in the soluble (R Al X or TiCl) portions of Ziegler catalysts or by using $SnPh_4$/$AlBr_3$/vanadium halide type catalysts. It has also been claimed[166] that molecular weight distribution in a metal alkyl-metal halide catalized process can be controlled by control of reaction temperature provided that both the olefin added and the polymer formed are dissolved in the reaction medium.

The thought has been expressed that narrow molecular weight distribution also results when the titanium or other transition metal is almost all in one lower valence state; as the percentage in various valence states increases, the molecular weight range of the product produced is believed to be broader.

PETROCHEMICAL DEVELOPMENTS 1960

Polyolefin Processes Today

This, then, is the state of the art of polyolefin resin processes (as well as we are able to discern it) in 1960. The outstanding product properties which have fostered the phenomenal growth of polyolefin manufacture over the last 20 years will undoubtedly continue to place new polyolefin products in new uses.

ACKNOWLEDGMENT

The author wishes to thank John J. McKetta, Thomas C. Ponder and Robert M. de Sombre of the PETROLEUM REFINER for their initial encouragement which prompted the writing of this manuscript. He also wishes to thank his Princeton neighbors: Gene Nowlin, Robert Jones and L. J. Croce at the FMC Research Center, and Cal Wolf and Tom Shepherd at Princeton Chemical Research, Inc. for reading and commenting on the manuscript. Thanks also are due to those in a major polyolefin-producing organization who offered comments, but who wish to remain anonymous.

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[60] Bloch, H. S. (to U.O.P.), U.S. 2,603,629, July 15, 1952.
[61] Boyd, T. (to Monsanto Chemical Co.), U.S. 2,606,179, Aug. 5, 1952.
[62] Van Dijk, C. P. and Van der Plas, F. J. F. (to Shell Dev. Co.), U.S. 2,618,626, Nov. 18, 1952.
[63] Barry, A. W. (to Du Pont), U.S. 2,646,425, July 21, 1953.
[64] Boyd, T. (to Monsanto Chemical Co.), U.S. 2,650,913, Sept. 1, 1953.
[65] Peters, E. F. and Evering, B. L. (to Standard Oil Co. (Ind.)), U.S. 2,658,059, Nov. 3, 1953.
[66] Boyd, T. and Dickey, R. M. (to Montsanto Chemical Co.), U.S. 2,666,756, Jan. 19, 1954.
[67] Howard, E. G., Jr. (to Du Pont), U.S. 2,683,140, July 6, 1954.
[68] Heiligmann, R. G. and Benington, F. (to Borden Co.), U.S. 2,685,575, Aug. 3, 1954.
[69] Cerveny, W. J., Burney, D. E., and Weisemann, G. H. (to Standard Oil Co. (Indiana)), U.S. 2,685,577, Aug. 3, 1954.
[70] Howard, E. G., Jr. (to Du Pont), U.S. 2,686,775, Aug. 17, 1954.
[71] Field, E. and Feller, M. (to Standard Oil Co. (Indiana)), U.S. 2,691,647, Oct. 12, 1954.
[72] Zletz, A. (to Standard Oil Co. (Ind.)), U.S. 2,692,257, Oct. 19, 1954.
[73] Roebuck, A. K. and Zletz A. (to Standard Oil Co. (Ind.)), U.S. 2,692,258, Oct. 19, 1954.
[74] Peters, E. F. (to Standard Oil Co. (Ind.)), U.S. 2,692,259, Oct. 19, 1954.
[75] Peters, E. F. and Evering, B. L. (to Standard Oil Co. (Ind.)), U.S. 2,692,261, Oct. 19, 1954.
[76] Peters, E. F. (to Standard Oil Co. (Ind.)), U.S. 2,692,295, Oct. 19, 1954.
[77] Berry, K. L. and Salzberg, P. L. (to Du Pont), U.S. 2,692,868, Oct. 26, 1954.
[78] Ziegler, K. and Gellert, H., U.S. 2,699,457, Jan. 11, 1955.
[79] Peters, E. F. (to Standard Oil Co. (Ind.)), U.S. 2,700,663, Jan. 25, 1955.
[80] Hoeksema, H. and Peters, E. F. (to Standard Oil Co. (Ind.)), U.S. 2,702,288, Feb. 15, 1955.
[81] Newberg, R. G., Wilson, H. L., and Sayko, A. F. (to Esso Res. Eng. Co.), U.S. 2,706,719, Apr. 19, 1955.
[82] Seelig, H. S. (to Standard Oil Co. (Ind.)), U.S. 2,710,854, June 14, 1955.
[83] McArthur, R. E. and Logan, J. S. (to Olin Mathieson Chem. Corp.), U.S. 2,713,044, July 12, 1955.
[84] Van der Plas, F. J. F. and Van Dijk, C. P. (to Shell Dev. Co.), U.S. 2,716,641, Aug. 30, 1955.
[85] Feller, M. and Field, E. (to Standard Oil Co. (Ind.)), U.S. 2,717,888, Sept. 13, 1955.
[86] Feller, M. and Field, E. (to Standard Oil Co. (Ind.)), U.S. 2,717,889, Sept. 13, 1955.
[87] Van Dijk, C. P. and Van der Plas, F. J. F. (to Shell Dev. Co.), U.S. 2,719,143, Sept. 27, 1955.
[88] Anderson, A. W., and Merckling, N. G. (to Du Pont), U.S. 2,721,189, Oct. 18, 1955.
[89] Mosher, R. A. (to Standard Oil Co. (Ind.)), U.S. 2,725,374, Nov. 29, 1955.
[90] Park, H. F. and Bump, C. K. (to Monsanto Chemical Co.), U.S. 2,726,204, Dec. 6, 1955.
[91] Field, E. and Feller, M. (to Standard Oil Co. (Ind.)), U.S. 2,726,231, Dec. 6, 1955.
[92] Field, E. and Feller, M. (Standard Oil Co. (Ind.)), U.S. 2,726,234, Dec. 6, 1955.
[93] Evering, B. L., Roebuck, A. K., and Zletz, A. (to Standard Oil Co. (Ind.)), U.S. 2,727,023, Dec. 13, 1955.
[94] Field E., and Feller, M. (to Standard Oil Co. (Ind.)), U.S. 2,727,024, Dec. 13, 1955.
[95] Brown, H. C. (to Standard Oil Co. (Ind.)), U.S. 2,728,752, Dec. 27, 1955.
[96] Russum, L. W., Hatch, R. L., and Wiesemann, G. H. (to Standard Oil Co. (Ind.)), U.S. 2,728,753, Dec. 27, 1955.
[97] Evering, B. L. and Peters, E. F. (to Standard Oil Co. (Ind.)), U.S. 2,728,754, Dec. 27, 1955.
[98] Weisemann, G. H. (to Standard Oil Co. (Ind.)), U.S. 2,728,755, Dec. 27, 1955.
[99] Friedlander, H. N. (to Standard Oil Co. (Ind.)), U.S. 2,728,756, Dec. 27, 1955.
[100] Field, E. and Feller, M. (to Standard Oil Co. (Ind.)), U.S. 2,728,757, Dec. 27, 1955.
[101] Field, E. and Feller, M. (to Standard Oil Co. (Ind.)), U.S. 2,728,-758, Dec. 27, 1955.
[102] Field, E. and Feller, M. (to Standard Oil Co. (Ind.)), U.S. 2,731,-452, Jan. 17, 1956.
[103] Field, E. and Feller, M. (to Standard Oil Co. (Ind)), U.S. 2,731,-453, Jan. 17, 1956.
[104] Smith, W. C. and Thomas, R. M. (to Esso Res. & Eng. Co.), U.S. 2,734,047, Feb. 7, 1956.
[105] Meyer, R. H. M. (to Shell Dev. Co.), U.S. 2,754,289, July 10, 1956.
[106] Heiligmann, R. G. and Stickney, P. B. (to Borden Co.), U.S. 2,758,107, Aug. 7, 1956.
[107] Pease, D. C. and Roedel, M. J. (to Du Pont), U.S. 2,762,791, Sept. 11, 1956.
[108] Heiligmann, R. G. and Stickney, P. B. (to Borden Co.), U.S. 2,765,297, Oct. 2, 1956.
[109] Field, E. and Feller, M. (to Standard Oil Co. (Ind.)), U.S. 2,767,-160, Oct. 16, 1956.
[110] Field, E. and Feller, M. (to Standard Oil Co. (Ind.)), U.S. 2,771,463, Nov. 20, 1956.
[111] Hagemeyer, H. J., Jr. (to Eastman Kodak Co.), U.S. 2,772,259, Nov. 27, 1956.
[112] Field, E. and Feller, M. (to Standard Oil Co. (Ind.)), U.S. 2,773,053, Dec. 4, 1956.
[113] Zletz, A. (to Standard Oil Co. (Ind.)), U.S. 2,780,617, Feb. 5, 1957.
[114] Ziegler, K. and Wilke, G., and Holzkamp, E., U.S. 2,781,410, Feb. 12, 1957.
[115] Dannels, B. F. (to Olin Mathieson Chem. Corp.), U.S. 2,788,340, Apr. 9, 1957.
[116] Feller, M. and Field, E. (to Standard Oil Co. (Ind.)), U.S. 2,791,575, May 7, 1957.
[117] Field, E. and Feller, M. (to Standard Oil Co. (Ind.)), U.S. 2,791,576, May 7, 1957.
[118] Feller, M. and Field, E. (to Standard Oil Co. (Ind.)), U.S. 2,795,-574, June 11, 1957.
[119] Anderson, A. W., Merckling, N. G., and Settlage, P. A. (to Du Pont), U.S. 2,799,668, July 16, 1957.
[120] Hanson, G. E. (to Phillips Petroleum Co.), U.S. 2,801,234, July 30, 1957.
[121] Feller, M. and Field, E. (to Standard Oil Co. (Ind.)), U.S. 2,802,-814, Aug. 13, 1957.
[122] Van Dijk, C. P. and Van der Plas, F. J. F. (to Shell Dev. Co.), U.S. 2,813,850, Nov. 19, 1957.
[123] Larchar, A. W. and Pease, D. C. (to Du Pont), U.S. 2,816,883, Dec. 17, 1957.
[124] Kagan, F. (to Standard Oil Co. (Ind.)), U.S. 2,819,257, Jan. 7, 1958.
[125] Spaenig, H. and Hensel, H. R. (to B.A.S.F.), U.S. 2,820,778, Jan. 21, 1958.
[126] Dale, C. H. (to Standard Oil Co. (Ind.)), U.S. 2,820,779, Jan. 21, 1958.

[127] Brebner, D. L., Bruce, J. M., and Stamatoff, G. S. (to Du Pont), U.S. 2,822,357, Feb. 4, 1958.
[128] Peters, E. F. and Evering, B. L. (to Standard Oil Co. (Ind.)), U.S. 2,824,089, Feb. 18, 1958.
[129] Edwards, M. B. and Hagemeyer, H. J., Jr. (to Eastman Kodak Co.), U.S. 2,824,090, Feb. 18, 1958.
[130] Hogan, J. P. and Banks, R. L. (to Phillips Petr. Co.), U.S. 2,825,721, Mar. 4, 1958.
[131] Cines, M. R. (to Phillips Petroleum Co.), U.S. 2,827,444, Mar. 18, 1958.
[132] Bartolomeo, F. A., Ledbetter, H. D., and McDuff, J. M. (to Dow Chemical Co.), U.S. 2,827,445, Mar. 18, 1958.
[133] Breslow, D. S. (to Hercules Powder Co.), U.S. 2,827,446, Mar. 18, 1958.
[134] Nowlin, G. and Lyons, H. D. (to Phillips Petroleum Co.), U.S. 2,827,-447, Mar. 18, 1958.
[135] Fotis, P., Jr. and Esmay, D. L. (to Standard Oil Co. (Ind.)), U.S. 2,829,136, April 1, 1958.
[136] Biddle, J. W. and Davison, J. M. (to Union Carbide Corp.), U.S. 2,831,845, Apr. 22, 1958.
[137] Nowlin, G. and Lyons, H. D. (to Phillips Petroleum Co.), U.S. 2,832,759, Apr. 29, 1958.
[138] Coover, H. W., Jr. (to Eastman Kodak Co.), U.S. 2,833,755, May 6, 1958.
[139] Akerlof, G. C. (to Callery Chemical Co.), U.S. 2,834,055, May 13, 1958.
[140] Friedlander, H. N. (to Standard Oil Co. (Ind.)), U.S. 2,834,768, May 13, 1958.
[141] Feller, M. and Field, E. (to Standard Oil Co. (Ind.)), U.S. 2,834,769, May 13, 1958.
[142] Hanson, G. E. and Crolcy, L. B. (to Phillips Petr. Co.), U.S. 2,837,504, June 3, 1958.
[143] Roelen, O., Kolling, H., Geiser, N., and Stiebling, E. (to Ruhrchemie A.G.), U.S. 2,838,477, June 10, 1958.
[144] Davison, J. M. and Erdmann, J. F. (to Union Carbide Corp.), U.S. 2,838,515, June 17, 1958.
[145] Drebner, D. L. (to DuPont), U.S. 2,839,518, June 17, 1958.
[146] Seed, L. (to I.C.I.), U.S. 2,839,519, June 17, 1958.
[147] Field, E., Friedlander, H. N., and Juveland, O. O. (to Standard Oil Co. (Ind.)), U.S. 2,840,551, June 24, 1958.
[148] Foster, W. E. (to Ethyl Corp.), U.S. 2,841,574, July 1, 1958.
[149] Friedlander, H. N., Juveland, O. O., and Field, E. (to Standard Oil Co. (Ind.)), U.S. 2,843,577, July 15, 1958.
[150] Pennington, E. N. and Cottle, J. E. (to Phillips Petr. Co.), U.S. 2,845,409, July 29, 1958.
[151] Heyson, G. H. (to Du Pont), U.S. 2,845,412, July 29, 1958.
[152] Schutze, H. G. (to Esso Res. & Eng. Co.), U.S. 2,845,414, July 29, 1958.
[153] Hogan, J. P. and Banks, R. L. (to Phillips Petroleum Co.), U.S. 2,846,425, Aug. 5, 1958.
[154] Larson, W. E. and Edmonson, R. E. (to Dow Chemical Co.), U.S. 2,846,426, Aug. 5, 1958.
[155] Findlay, R. A. (to Phillips Petr. Co.), U.S. 2,846,427, Aug. 5, 1958.
[156] Cines, M. R. (to Phillips Petroleum Co.), U.S. 2,849,429, Aug. 26, 1958.
[157] Foster, R. E. and Whitman, G. M. (to Du Pont), U.S. 2,851,451, Sept. 9, 1958.
[158] Richard, W. R., Jr., Stewart, R. K., and Calfee, J. D. (to Monsanto Chemical Co.), U.S. 2,852,501, Sept. 16, 1958.
[159] Fields, R. T. (to Du Pont), U.S. 2,854,320, Sept. 30, 1958.
[160] Richard, W. R., Jr. and Jones, N. E. (to Monsanto Chemical Co.), U.S. 2,856,395, Oct. 14, 1958.
[161] Cottle, J. E. (to Phillips Petr. Co.), U.S. 2,858,902, Nov. 4, 1958.
[162] Lanning, W. C. (to Phillips Petroleum Co.), U.S. 2,860,125, No. 11, 1958.
[163] Cines, M. R. (to Phillips Petroleum Co.), U.S. 2,860,126, Nov. 11, 1958.
[164] Banks, R. L. (to Phillips Petroleum Co.), U.S. 2,860,127, Nov. 11, 1958.
[165] Fotis. F., Jr. (to Standard Oil Co. (Ind.)), U.S. 2,861,983, Nov. 28, 1958.
[166] Anderson, A. W., Bruce, J. M., Jr., and Fallwell, E. L. (to Du Pont) U.S. 2,862,917, Dec. 2, 1958.
[167] Seed, L. (to I. C. I.), U.S. 2,865,903, Dec. 23, 1958.
[168] Seed, L. and Pajaczkowski, A. (to I. C. I.), U.S. 2,865,904, Dec. 23, 1958.
[169] Pieper, G., Stein, E., and Rickert, H. (to Farbenfabriken Bayer, A.G.), U.S. 2,867,612, Jan. 6, 1959.
[170] Ray, R. L. and Sistrunk, T. O. (to Ethyl Corp.), U.S. 2,868,771, Jan. 13, 1959.
[171] Ray, R. L. and Sistrunk, T. O. (to Ethyl Corp.), U.S. 2,868,772, Jan. 13, 1959.
[172] Davison, J. M. and Erdmann, J. F. (to Union Carbide Corp.), U.S. 2,870,130, Jan. 20, 1959.
[173] Guillet, J. E. and Coover, H. W., Jr. (to Eastman Kodak Co.), U.S. 2,870,131, Jan. 20, 1959.
[174] Gresham, W. F. and Merckling, N. G. (to Du Pont), U.S. 2,872,439, Feb. 3, 1959.
[175] Bowman, L. W. and Leary, R. F. (to Esso Res. & Eng. Co.), U.S. 2,874,153, Feb. 17, 1959.
[176] Schmerling, L. (to U.O.P.), U.S. 2,878,240, Mar. 17, 1959.
[177] Schneider, A. (to Sun Oil Co.), U.S. 2,878,241, Mar. 17, 1959.
[178] Anderson, A. W. and Bro, M. I. (to Du Pont), U.S. 2,879,263, Mar. 24, 1959.
[179] Thompson, W. E. (to Sun Oil Co.), U.S. 2,880,121, Mar. 31, 1959.
[180] Kolling, H. and Stiebling, E. (to Ruhrchemie, A.G.), U.S. 2,880,163, Mar. 31, 1959.
[181] Lanning, W. C. (to Phillips Petroleum Co.), U.S. 2,880,198, Mar. 31, 1959.
[182] Jezl, J. L. (to Sun Oil Co.), U.S. 2,880,199, Mar. 31, 1959.
[183] Feller, M. and Field, E. (to Standard Oil Co. (Ind.)), U.S. 2,880,200, Mar. 31, 1959.
[184] Peters, E. F. and Evering, B. L. (to Standard Oil Co. (Ind.)), U.S. 2,880,201, Mar. 31, 1959.
[185] Pilar, F. L., Friedlander, H. N., Juveland, O. O., and Field, E. (to Standard Oil Co. (Ind.)), U.S. 2,881,156, Apr. 7, 1959.
[186] Natta, G., Pino, P., and Mazzanti, G. (to Montecatini), U.S. 2,882,263, Apr. 14, 1959.
[187] Barnes, E. B., Thomson, J. E., and Dlumb, J. A. (to Dow Chemical Co.), U.S. 2,882,264, Apr. 14, 1959.
[188] Stamatoff, G. S. (to Du Pont), U.S. 2,883,372, Apr. 21, 1959.
[189] Bo, G. M. M., Fournet, A., Phelisse, J. A., and Fichet, E. (to Soc. des Usines Chim. Rhone-Poulenc), U.S. 2,884,409, Apr. 28, 1959.
[190] Schappert, H. M. (to Koppers Co., Inc.), U.S. 2,885,389, May 5, 1959.
[191] Weber, H., Boehm, H., Schiller, G., and Stange, K. (to B.A.S.F.), U.S. 2,886,560, May 12, 1959.
[192] Reynolds, W. B. and Ashe, B. H., Jr. (to Phillips Petroleum Co.), U.S. 2,886,561, May 12, 1959.
[193] Calfee, J. D. and Erbaugh, L. E. (to Monsanto Chemical Co.), U.S. 2,887,445, May 19, 1959.
[194] Shearer, N. H., Jr. and Coover, H. W., Jr. (to Eastman Kodak Co.), U.S. 2,887,471, May 19, 1959.
[195] Fotis, P., Jr. (to Standard Oil Co. (Ind.)), U.S. 2,887,472, May 19, 1959.
[196] Balthis, J. H., Jr. (to Du Pont), U.S. 2,887,473, May 19, 1959.
[197] Gresham, W. F. and Merckling, N. G. (to Du Pont), U.S. 2,888,448, May 26, 1959.
[198] Fritz, R. J. (to Esso Res. & Eng. Co.), U.S. 2,889,314, June 2, 1959.
[199] Murray, P. B. (to Sun Oil Co.), U.S. 2,890,212, June 9, 1959.
[200] Brightbill, E. N. and Lindland, K. P. (to Du Pont), U.S. 2,890,214, June 9, 1959.
[201] Linn, W. J. (to Du Pont), U.S. 2,891,040, June 16, 1959.
[202] Matlack, A. S. (to Hercules Powder Co.), U.S. 2, 891,041, June 16, 1959.
[203] Matlack, A. S. (to Hercules Powder Co.), U.S. 2,891,042, June 16, 1959.
[204] Matlack, A. S. (to Hercules Powder Co.), U.S. 2,891,043, June 16, 1959.
[205] Matlack, A. S. (to Hercules Powder Co.), U.S. 2,891,044, June 16, 1959.
[206] Lanning, W. C. (to Phillips Petroleum Co.), U.S. 2,891,935, June 23, 1959.
[207] Guillet, J. C. and Coover, H. W., Jr. (to Eastman Kodak Co.), U.S. 2,891,936, June 23, 1959.
[208] Reed, H. W. B. and Lawley, H. G. (to I.C.I.), U.S. 2,891,937, June 23, 1959.
[209] Peters, E. F. and Evering, B. L. (to Standard Oil Co. (Ind.)), U.S. 2,892,826, June 30, 1959.
[210] Seelbach, Cl W. and McCulloch, W. J. G. (to Esso Res. & Eng. Co.), U.S. 2,893,984, July 7, 1959.
[211] Powelson, R. V. N. (to Sun Oil Co.), U.S. 2,893,985, July 7, 1959.
[212] Lanning, W. C. (to Phillips Petroleum Co.), U.S. 2,894,824, July 14 1959.
[213] Christl, R. J. and Roedel, M. J. (to Du Pont), U.S. 2,897,183, July 28, 1959.
[214] Kimble, H. S. and McLeod, N. F. (to Phillips Petroleum Co.), U.S. 2,897,184, July 28, 1959.
[215] Peters, E. F. and Evering, B. L. (to Standard Oil Co. (Ind.)), U.S. 2,898,326, Aug. 4, 1959.
[216] McCulloch, W. J. G. and Langer, A. W., Jr. (to Esso Res. & Eng. Co.), U.S. 2,898,327, Aug. 4, 1959.
[217] Reed, H. W. B. and Mitchell, W. E. A. (to I.C.I.), U.S. 2,898,328, Aug. 4, 1959.
[218] Kittleson, A. R. (to Esso Res. & Eng. Co.), U.S. 2,898,329, Aug. 4, 1959.
[219] Isbenjian, H. (to Aries Associates), U.S. 2,898,330, Aug. 4, 1959.
[220] Hagenmeyer, H. J., Jr. and Edwards, M. B. (to Eastman Kodak Co.), U.S. 2,899,413, Aug. 11, 1959.
[221] Mertes, T. S. (to Sun Oil Co.), U.S. 2,899,414, Aug. 11, 1959.
[222] Truett, W. L. (to Du Pont), U.S. 2,899,415, Aug. 11, 1959.
[223] Schveyer, R. C. (to Du Pont), U.S. 2,899,416, Aug. 11, 1959.
[224] Hooker, G. W. (to Koppers Co., Inc.), U.S. 2,899,417, Aug. 11, 1959.
[225] Reynolds, W. B. (to Phillips Petroleum Co.), U.S. 2,899,418, Aug. 11, 1959.
[226] Chambers, R. R., Elkins, R. H., and Monagle, J. J. (to Sinclair Refining Co.), U.S. 2,899,419, Aug. 11, 1959.
[227] Gresham, W. F. and Merckling, N. G. (to Du Pont), U.S. 2,900,372, Aug. 18, 1959.
[228] Martin, J. W., Jr. (to Koppers Co., Inc.), U.S. 2,900,373, Aug. 18, 1959.
[229] Aries, R. S., U.S. 2,900,373, Aug. 18, 1959.
[230] Oita, K. and Nevitt, T. D. (to Standard Oil Co. (Ind.)), U.S. 2,903,404, Sept. 8, 1959.
[231] Brown, D. E., Keller, J. P., and Watson, A. T. (to Esso Res. & Eng. Co.), U.S. 2,904,486, Sept. 15, 1959.
[232] Fasce, E. V. and Gull, N. L. (to Esso Res. & Eng. Co.), U.S. 2,904,542, Sept. 15, 1959.
[233] Anderson, A. W., Bruce, J. M. Jr., Merckling, N. G., and Truett, W. L. (to Du Pont), U.S. 2,905,645, Sept. 22, 1959.
[234] Natta, G. and Longi, P. (to Montecatini), U.S. 2,905,646, Sept. 22, 1959.
[235] Miller, F. F. and Conner, D. S. (to Goodrich-Gulf Chem., Inc.), U.S. 2,905,659, Sept. 22, 1959.
[236] Muehlbauer, H. and Weber, H. (to B.A.S.F.), U.S. 2,905,661, Sept. 22, 1959.
[237] Thonka, L. M. (to Dow Chemical Co.), U.S. 2,906,742, Sept. 29, 1959.
[238] Ballard, W. P., Gibson, J. R., and Fort, B. F., Jr. (to Texaco, Inc.), U.S. 2,906,795, Sept. 29, 1959.
[239] Merckling, N. G. (to Du Pont), U.S. 2,907,757, Oct. 6, 1959.
[240] Hagemeyer, H. J., Jr. and Edwards, M. B. (to Eastman Kodak Co.), U.S. 2,908,669, Oct. 13, 1959.
[241] Hagemeyer, H. J., Jr. and Edwards, M. B. (to Eastman Kodak Co.), U.S. 2,908,670, Oct. 13, 1959.
[242] Hochgraf, N. N., Kenyon, L. C., Jr., and Langer, A. W., Jr. (to Esso Res. & Eng. Co.), U.S. 2,908,671, Oct. 13, 1959.
[243] Nowlin, G. and Lyons, H. D. (to Phillips Petroleum Co.), U.S. 2,908,674, Oct. 13, 1959.
[244] Lindland, K. P. (to Du Pont), U.S. 2,908,675, Oct. 13, 1959.
[245] Cottle, J. E. (to Phillips Petroleum Co.), U.S. 2,908,734, Oct. 13, 1959.
[246] Thomas, W. W. (to Hercules Powder Co.), U.S. 2,909,510, Oct. 20, 1959.
[247] Thomas, W. W. (to Hercules Powder Co.), U.S. 2,909,511, Oct. 20, 1959.
[248] Bruce, J. M., Jr. (to Du Pont), U.S. 2,909,512, Oct. 20, 1959.
[249] Overbaugh, S. C. (to Du Pont), U.S. 2,909,513, Oct. 20, 1959.
[250] Nowlin, G. and Lyons, H. D. (to Phillips Petroleum Co.), U.S. 2,910,461, Oct. 27, 1959.
[251] Bull, W. C., Cain, J. H., Spomer, R. J., Finkbeiner, H. L., Jr., and Hill, R. W. (to Spencer Chemical Co.), U.S. 2,911,399, Nov. 3, 1959.
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About the Author

Sittig

Marshall Sittig is currently Assistant Director of the Office of Research Administration of a large eastern university. His spare time is devoted to writing objective reviews of the petrochemical field. Mr. Sittig has been associated with various companies having spent seven years with DuPont and five years with Ethyl Corp. He has a B.S. in Chemical Engineering from Purdue University and did some graduate work in chemistry.

This Article in Book Form

Due to the increasing interest and importance attached to this subject by industry, this article will be printed in hard-back book form. However, in addition, this book will be completely indexed and will list all U.S. polyolefin patents in order of application. This listing contains patent application serial number, date, U.S. patent number and book reference number.

This book will be available for purchase in March, 1961 from Gulf Publishing Co.'s Book Publishing Division. However, you can reserve your copy now by circling E-37 on the green card in the back of the book and sending it in today.

A SPECIAL REPORT

Which Acetylene Feed Is Best?

Here is how feed, fuel, oxygen, and investment affects the overall cost of acetylene from paraffin feedstocks

Daniel C. Lockwood
C F Braun and Co., Alhambra, Calif.

PRICE AND YIELD are often the most important factors in selecting a feedstock for chemical manufacture. But the feed that yields the most product per dollars worth of feed is not always the most economic. This advantage may be more than offset by the lower utilities or lower plant cost for another feedstock. Study of the reactions involved can often tell if there are such offsetting factors. Such is the case for the manufacture of acetylene from paraffin hydrocarbons.

Methane, ethane, and propane will be used here to show the effect of feedstock on plant cost and manufacturing costs. These three feeds are chosen because they show these effects, and their trends, most dramatically. The effect of changing from a propane to butane feed is small as compared to changing from methane to ethane.

REACTIONS

The over-all reactions for converting methane, ethane, and propane to acetylene by thermal decomposition, are as follows.

$$2CH_4 \rightarrow C_2H_2 + 3H_2 \quad (1)$$

$$C_2H_6 \rightarrow C_2H_2 + 2H_2 \quad (2)$$

$$2C_3H_8 \rightarrow 3C_2H_2 + 5H_2 \quad (3)$$

In partial-oxidation reactors, combustion reactions occur concurrently with these acetylene-producing re-

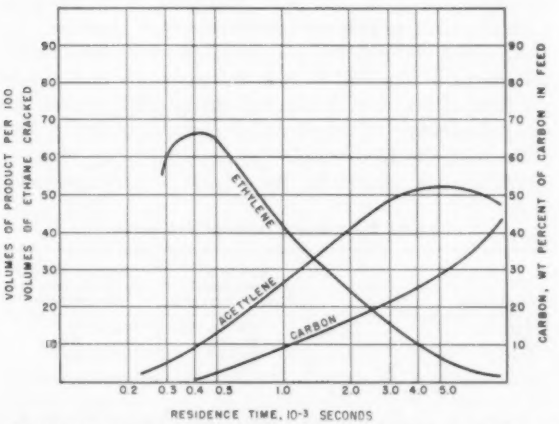

FIGURE 1—In this data[2] (above) for the pyrolysis of ethane at 1400 °C, notice how somewhat longer residence time favors the production of acetylene.

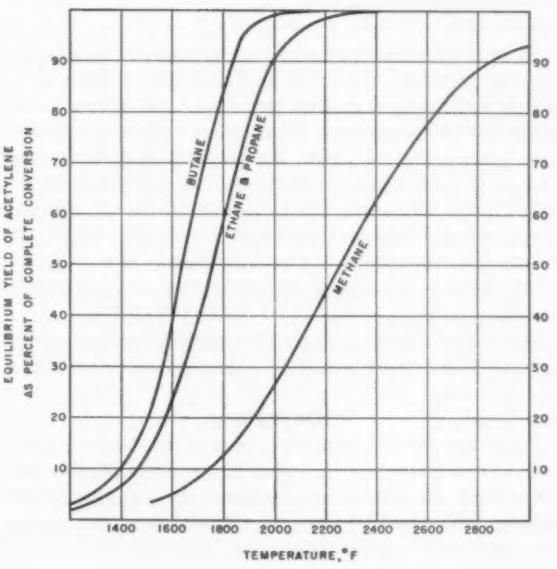

FIGURE 2—Shows (right) that to obtain the most favorable conditions from an equilibrium point-of-view, the reaction temperature must go up as the molecular weight of the feed goes down.

actions. In the so called flame-type reactors, the feed is mixed with hot, combustion products that come from another part of the reactor. Thus, in both partial-oxidation and flame-type reactions, the products of other reactions are mixed with the reactants and products of these acetylene-producing reactions.

These concurrent reactions, or the products from these other reactions, can have an effect on the acetylene-producing reactions. These effects will be discussed later. But first it is important to consider the acetylene-producing reactions by themselves. A good place to start is the actual mechanism for each reaction and the relative rates for each step.

Kassel[1] proposed a four step reaction for the thermal decomposition of methane to acetylene as in Reaction 1 above. These four steps are as follows:

$$CH_4 \longrightarrow CH_2{=} + H_2 \quad (4)$$

$$CH_2{=} + CH_4 \longrightarrow C_2H_6 \quad (5)$$

$$C_2H_6 \longrightarrow C_2H_4 + H_2 \quad (6)$$

$$C_2H_4 \longrightarrow C_2H_2 + H_2 \quad (7)$$

Work by other investigators[2, 3, 4, 5, 6] support this mechanism and propose mechanisms for the decomposition of heavier hydrocarbons. In the case of ethane, the proposed route is straight dehydrogenation as in Reactions 6 and 7. For propane cracking, the proposed mechanism is that the dehydrogenation steps are preceded by demethanization. Thus, after the primary cracking reactions, the mechanism for the three feeds is identical.

Most of the work done[2, 3, 7, 8, 9] indicates that for the conditions used in the production of acetylene from light hydrocarbons, the dehydrogenation of ethylene has the slowest rate. There is contradictory evidence[2, 4] as to whether the rate for the demethanization of propane is significant. Recent work by Reid and Linden[10] indicates that for propane and heavier feedstocks, reactions other than the dehydrogenation of ethylene may control reaction rate.

A final reaction follows the dehydrogenation of ethylene to acetylene, Reaction 7. This final reaction is the decomposition of acetylene to carbon and hydrogen. To keep this decomposition from being significant, and to give high acetylene yields, the reaction must be carried out at a high temperature and at a short residence time.[11, 12, 13] This lets the acetylene-producing reaction go ahead at a fast rate, yet stops the reaction before the subsequent decomposition becomes significant.

Figure 1 shows data gathered by Tropsch and Egloff[2] for the pyrolysis of ethane at 1,400° C. This figure shows graphically how Reactions 6, 7, and final decomposition of acetylene to carbon and hydrogen, follow one another.

EQUILIBRIUM

The thermal decomposition of hydrocarbons to acetylene is not a reaction that goes to complete equilibrium. The final decomposition products are, as mentioned above, carbon and hydrogen. Nonetheless, computing the equilibrium compositions for Reactions 1, 2, and 3 can be helpful in predicting the conditions that may be most favorable for acetylene manufacture.

Temperature. To determine the effect of temperature on chemical equilibrium, equilibrium compositions were computed for Reactions 1, 2, and 3, using free energies of formation. The moles of acetylene per mole of feed, at equilibrium, were divided by mols of acetylene per mol of feed at complete conversion to acetylene, as defined by Reactions 1, 2, and 3. The resulting equilibrium yield of acetylene as a percent of complete conversion, is plotted against temperature in Figure 2. To help illustrate the trend, a curve is also shown for the conversion of butane to acetylene. Figure 2 shows that to obtain the most favorable conditions from an equilibrium point-of-view, the reaction temperature must go up as the molecular weight of the feed goes down.

Pressure. Another variable that can affect equilibrium is pressure. Reactions 1, 2, and 3 show that four volumes of product are produced per volume of feed in propane cracking, as against three for one in ethane cracking and two for one in methane. Thus another conclusion is that increasing pressure will adversely affect equilibrium of heavier feeds more than it will affect the equilibrium of light feeds.

YIELDS

If feedstocks were completely converted to acetylene as in Reactions 1, 2, and 3, the yields would be as shown in Table 1.

TABLE 1—Yields for Complete Conversion to Acetylene

Feedstock	Yield, Mol Percent	Yield, Weight Percent
CH_4	50	81
C_2H_6	100	87
C_3H_8	150	89

Actually, as mentioned above the pyrolysis to acetylene does not go to completion. Reported yields from semi-commercial and commercial size reactors[14, 15, 16, 17, 18] give the data shown in Table 2. Methane yields are from partial-oxidation reactors and flame-type reactors. The yields are computed from reported yields by backing out the methane required to heat the reactants and to supply heat of reaction. Yields for ethane and propane are from flame-type or regenerative reactors in which fuels other than the feed supply the required heat. Thus, no adjustment is needed for the ethane or propane yields.

TABLE 2—Actual Yields of Acetylene

Feedstock	Range of Actual Yields, Weight Percent	Percent Actual Yield of Complete Conversion
CH_4	50—58	65
C_2H_6	47—49	55
C_3H_8	38—45	45

Table 1 shows higher yields for heavier feeds. But Table 2 shows the actual yields go in the opposite direction from the way the overall reactions predict. This can be explained as follows. Although reaction temperatures are not given in all references, the methane pyrolysis was probably carried out at close to 3,000° F and the ethane and propane cracking in the 2,500° F range.

If, for all cases, ethylene dehydrogenation, Reaction 7, is rate controlling, and if the residence time was about the same for all cases, the yield from methane should be higher than the yield from ethylene and propane. This is causd by the higher temperature which increases reaction rate and allows a closer approach to the equilibrium.

Further, if the rate of the propane demethanization reaction is significant as compared with the ethylene dehydrogenation reaction, and again if temperatures and residence times are about the same for ethane and propane cases, the yield from ethane should be higher than from propane. The pilot plant work of Tropsch and Egloff[2] supports this line of reasoning.

Summing up on yields, the over-all reactions show that at complete conversion there should be a slight upward trend in weight yields from various feedstocks as molecular weight increases. But the date reported above, plus theoretical rate and equilibrium considerations, show that the reactor conditions set up by a process licensor, can affect the yields so much that the relative yields at complete conversion are not significant.

HEAT REQUIREMENTS

In a partial oxidation type reactor, only about half the hydrocarbon feed goes toward the production of acetylene. The remaining half is burned to supply the heat of reaction and to heat the reactants to reaction temperature. Since the heat required to heat the reactants is roughly twice the heat required for the acetylene reaction, the temperature level of the reaction can be very important.

To get equilibrium conditions for satisfactory yields, the temperature level for methane pyrolysis must be higher than for ethane or propane cracking, as shown in figure 2. From the figures given above, roughly one-third of the feed is used to heat the reactors. Thus, the higher temperature required for methane cracking does, in effect, make a substantial reduction in the overall yield of acetylene from methane as compared to ethane and propane. This effect is shown in Table 3.

TABLE 3—Effect of Pyrolysis Temperature on Over-All Yield in Partial Oxidation Reactors

	Methane	Ethane	Propane
Cracking temperature, °F	3,000	2,600	2,500
Heat of reaction, Btu per pound of acetylene produced	7,000	5,600	5,300
Heating reactants, Btu per pound of acetylene produced	15,500	9,200	8,800
Total heat required, Btu per pound of acetylene produced	22,500	14,800	14,100
Heat of partial combustion, Btu per pound of feed burned	8,700	8,500	8,300
Cracking yield in weight percent of feed to cracking	55	48	40
Overall yield, in weight percent of total feed including feed burned	23	26	24

The computations for the figures in Table 3 have the following basis. Preheat temperature for hydrocarbon feed and oxygen is 750° F. About 85 percent of the carbon burned goes to carbon monoxide with the remaining 15 percent going to carbon dioxide. About half the hydrogen associated with the hydrocarbon burned goes to water.[14]

Table 3 shows not only that the heat required to heat reactants decreases substantially with increasing molecular weights of feed, but also the actual heat of reaction decreases. These trends are partially offset by the decrease in the heat of partial combustion as the feeds gets heavier. But the over-all effect of the lower heat requirements is to overcome the cracking yield trend shown in Table 2, and to make the over-all yields substantially the same for the reaction conditions used in Table 3.

All the above comments are based on a partial-oxidation type of reactor. In a flame-type reactor, where hot combustion gases are mixed with the feed to be cracked, the lower heat requirements could show up as lower fuel requirements instead of changing yield as in partial oxidation. The same would be true for regenerative-type reactors.

With less fuel being required for heavier feeds, less hydrogen is produced in the partial combustion, and less hydrogen is introduced into the products from the acetylene-producing reaction. The effect of this is to produce more favorable equilibrium conditions for the acetylene-producing reaction. This is partially offset, however, by the fact that at the same total pressure, fewer combustion products increase the partial pressure of the products of the acetylene-producing reaction, and thus tend to produce less favorable equilibrium conditions.

OXYGEN REQUIREMENTS

In addition to yield and heat requirement, the amount of oxygen used is a factor in feed selection. For heavier feedstocks, some process licensors are using air as the source of oxygen. This may seem to reduce the importance of oxygen as a cost in the manufacture of acetylene, as compared with the use of say 95 percent oxygen. But such is not the case.

If air is used as a source of oxygen, the concentration of acetylene in the burner offgas is reduced. This roughly doubles the amount of gas that must be processed in the recovery and purification section of the acetylene plant. The fuel required to heat the reactants is increased because of the nitrogen in the air. In addition, the value of the residual gas as fuel or for chemical manufacture is reduced by its nitrogen content. These factors offset the cost of an oxygen plant.[16]

Thus oxygen, be it from air or from industrial grade oxygen, should be considered in choosing a feedstock for acetylene manufacture. As discussed above in connection with heat requirements, the heat required for reaction and to preheat reactants, is higher for methane than for ethane or propane. Oxidation of feed, or some other fuel supplies this heat.

For the conditions of Table 3, ethane feed requires roughly 10-percent more oxygen than does propane feed. And methane feed require some 50-percent more oxygen than does ethane. Thus the cost of oxygen goes down as the molecular weight of the feedstock goes up.

VOLUME OF REACTION PRODUCTS

The volume of reaction products per volume of acetylene produced affects the cost of the compression, recovery, and purification sections of the acetylene plant. The type of feedstock influences the volume of reaction products in two ways.

First, consider the overall reactions for the production of acetylene, Reactions 1, 2, and 3. For methane feed, Reaction 1, three volumes of hydrogen are produced

per volume of acetylene. For ethane feed, two volumes of hydrogen are produced per volume of acetylene. And for propane, 1⅔ volumes are produced per volume of acetylene.

Second, note the influence on reactor effluent volume of heat requirement and combustion products. Consider for example, a typical reactor effluent composition, from a partial oxidation reactor, using methane as a feedstock[14] as shown in Table 4.

TABLE 4—Reactor Effluent Composition

	Volume Percent
CH_4	6.5
C_2H_2	8.5
C_2H_4 plus	0.8
H_2	54.3
CO	25.2
CO_2	3.8
N_2	0.9
	100.0

As mentioned above, for methane cracking, three volumes of hydrogen are produced for each mol of acetylene produced. Thus 25.5 moles of the hydrogen in the effluent of Table 4 are from cracking. The remaining 28.8 moles of hydrogen come principally from the partial combustion, or roughly one mole of hydrogen for each mole of carbon oxides formed. Thus, almost 60 percent of the reactor effluent volume comes from combustion products.

The combination of hydrogen produced and combustion products has a significant effect on the total volume of the reactor effluent. Based on the conditions in Table 3, the reactor effluent from ethane cracking is about 75 percent of that from methane cracking. For propane cracking, the effluent is roughly 70 percent of that from methane cracking.

SUMMARY

Four factors should be considered when selecting the feed stock for acetylene manufacture. These factors are:

1 Basic yield of acetylene from feed pyrolysis,

2 Heat requirement as it affects yield or fuel costs,

3 Oxygen requirement, and

4 Volume of reaction effluent.

The first two factors, basic yield and heat requirement, when combined, do not significantly affect overall yield. But the last two factors, oxygen requirement and volume of reactor effluent, both favor heavier feedstocks. Thus, the price of the lighter feedstock must be lower to offset these last two factors.

The manufacturing cost for acetylene by a modern, partial oxidation process is shown in Table 5. This manufacturing cost is based on methane as a feedstock. It shows the relative importance of the factors affecting feedstock choice. Feedstock itself is 30 percent of the manufacturing cost. Oxygen is about 35 percent of the total manufacturing cost. And items based on first cost—depreciation, maintenance, and some prorated costs—are about 30 percent of the total. The remaining 5 percent, plus the offgas credit, covers the cost of labor, utilities, chemicals, and royalty.

TABLE 5—Acetylene Manufacturing Cost
Modern Partial Oxidation Process

	Cents Per Pound of Acetylene
Direct Cost	
Raw Materials	
Natural gas at $.20/1000 scf	2.05
Oxygen at $9/ton	2.45
Operating labor at $3/hr	0.22
Maintenance, at 4 percent of investment	0.42
Utilities	0.63
Chemicals	0.06
Royalty	0.30
Total Direct Cost	6.13
Offgas credit as fuel, at $.20/mm Btu	1.08
Net Direct Cost	5.05
Prorated Cost	
Operating labor plus half maintenance x 140	0.60
Fixed Charges	
Depreciation at 10 percent of investment	1.05
Property tax and insurance at 1 percent	0.11
Manufacturing Cost	6.81

For a typical Gulf Coast situation, natural gas might cost from 20 to 25 cents per thousand scf, and propane might cost something over 4 cents per gallon. This figures out at roughly 0.5 cents per pound for natural gas and some 1 cent per pound for propane. While natural gas has a clearcut cents-per-pound advantage, oxygen and plant investment are significant factors in the cost of making acetylene. They favor heavier feeds. Thus, it is necessary to get specific figures for feed, fuel, oxygen, and investment for the process under consideration before the best feedstock can be chosen.

About the Author

Daniel C. Lockwood is head of C F Braun Co.'s Process Engineering Department, Alhambra, Calif. A graduate of Stanford University with a B.A. degree in engineering in 1939, and an additional engineering degree in 1941, he has 20 years' experience in the process and project engineering of refineries and chemical plants. He has worked as a process engineer, senior process engineer, project manager, and department head for C F Braun.

Lockwood

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A SPECIAL REPORT

Which Isoprene Route Is Best?

With ample and properly priced isoprene assured from oil, the real question is—which commercial process will be the most economical

Victor J. Anhorn
The Goodyear Tire and Rubber Co.
Akron, Ohio

THE USE of stereospecific catalysts has opened a new field in synthetic rubbers. For the first time it is possible to produce a rubber equivalent to tree rubber.

The disclosure of the synthesis of *cis*-polyisoprene late in 1954 created a need for commercial quantities of the monomer, isoprene. Up to this time, except for a brief flurry during screening research for a synthetic rubber during World War II, only minor interest was shown toward the development of a process for producing isoprene. Commercial requirements principally for butyl rubber were met by steam cracking naphthas. However, when confronted with isoprene specifications required for the new stereospecific catalyst systems, this commercial isoprene was woefully inadequate.

This discovery of *cis*-polyisoprene came at an opportune time. Natural rubber consumption trends in the late 1950s indicated that unless the use ratio of natural rubber changed on the continent, a shortage of natural rubber could be expected during the early 1960s. With this prospect before them, natural rubber consumers began to look for potential isoprene producers among the petroleum and petrochemical industries. Considerable interest was aroused. Although no one was anxious to guarantee production of isoprene, many companies began to examine various synthetic routes to it.

Isoprene Cost. Even though the momentum originally generated continued to move along the isoprene research, many potential monomer producers were concerned with some paralleling developments. The market price for isoprene in tonnage quantities was not established although the 95 percent purity monomer available listed for 25 cents per pound. It was the opinion of some in the rubber industry, that to be on a firm basis in long range planning, isoprene should be produced at a price which would permit the manufacture and sale of *cis*-polyisoprene for not more than 25 cents per pound. Solvent polymerization of isoprene with stereospecific catalysts is more expensive than the conventional emulsion systems of SBR. Consequently, to produce rubber at a reasonable return on investment the isoprene selling price desirably should approach that of butadiene.

Polybutadiene. A second factor causing some concern was the announcement of *cis*-polybutadiene which was reported as a replacement or extender of natural rubber. If this new rubber assumed the role claimed for it, the possibility of a natural rubber shortage would not be as acute as originally anticipated. Potential isoprene suppliers were aware of the excess butadiene capacity. Some reasoned that the need for isoprene would be considerably delayed by the complete exploitation of *cis*-polybutadiene.

Isoprene Purity. A third factor was the purity requirement of isoprene. It was soon evident that the commercial isoprene available was far from polymerization grade. Isoprene specifications, written after exhaustive research, contained impurity levels in the low parts per million. Many potential isoprene producers believed that the purification required would add cost and therefore limit the profit margin in isoprene production.

It is a matter of record that the natural rubber shortage did not develop as early as anticipated. The use ratio of natural to synthetic rubber on the continent changed with the installation of SBR plants. The development abroad, however, did not check or deter research on new stereo rubbers. Process development in conjunction with research has indicated methods for making *cis*-polybutadiene and *cis*-polyisoprene to the extent that

commercial plants capable of producing 195,000 tons of rubber are expected to be on stream by late 1961. Due to the availability of tonnage quantities of butadiene some 110,000 tons of the total will be *cis*-polybutadiene.

The supply picture of isoprene needed for the *cis*-polyisoprene is beginning to take shape. Research on isoprene synthesis has paralleled *cis*-polyisoprene process development to the extent that isoprene will be available for the planned *cis*-polyisoprene production.

Isoprene Raw Materials. Numerous synthetic routes to isoprene have received attention in process researches up to and since 1955. Experience with butadiene indicated that to be successful commercially, the isoprene process should utilize low cost raw materials in abundant supply. The monomer produced should be free of impurities harmful to stereospecific catalysts. As pointed out before, sound, long range planning dictated that isoprene should be produced at costs which would permit *cis*-polyisoprene to be competitive with natural rubber at a market price of 25 cents per pound.

ISOPRENE PROCESSES

Of the various isoprene processes under investigation several appear to have gained sufficient maturity for commercialization. Economics of all processes have not been reported. It would appear that those under present consideration will produce isoprene at costs approaching butadiene cost. These isoprene synthesis can be divided into two categories:

1. The dehydrogenation of specific hydrocarbons having the required carbon skeleton.
2. Degradative reactions of specific compounds having the desired carbon—carbon skeletons.

Dehydrogenation of isopentane has been studied quite extensively. Success in butane dehydrogenation dictated this approach for isoprene synthesis. Studies made with isopentane however, showed high byproduct yields of piperylenes along with acetylenic impurities which cut into the economy of the process. The choice of methylbutenes as dehydrogenation charge stock does not appear to be plagued with these undesirable products. This process is reported to be the one used in preparing isoprene for the *cis*-polyisoprene now in commercial production. Conventional type butane or butene dehydrogenation equipment can be used with minor modifications. The methylbutenes required for dehydrogenation charge stock are isolated from light catalytic cracked stock. These olefins can also be produced from ethylene and propylene in a two step process using tripropylaluminum.

A degradative type of reaction is involved in a process recently developed in Europe. Isoprene is produced in a two step process. Isobutylene and formaldehyde form 4,4-dimethyl-m-dioxane which is decomposed over a solid catalyst to isoprene, water and formaldehyde. The latter is recovered for recycle to the first step. The isoprene produced is claimed to be of high purity. Charge stock for this process can be a isobutylene containing butane-butene refinery stream. It would appear that economic factors dictate that the formaldehyde requirements be produced at the isoprene site.

Dementhanation of methylpentenes to yield isoprene is a second degradative type reaction receiving attention for commercialization. Methylpentenes, predominantly 2-methyl-1-pentene, are formed in high process efficiency from a refinery propane-propene stream. The 2-methyl-1-pentene is isomerized to 2-methyl-2-pentene and the 2-methyl-2-pentene is subsequently cracked to isoprene. No impurities were formed which cause difficulty in subsequent polymerization to *cis*-polyisoprene.

Isoprene production seems fairly well on its way through the three processes listed above. Just how well each will fare when in commercial competition remains to be established. Fortunately each route requires a different feed stock which can be found in quantities in modern refineries. It is doubtful that processes utilizing higher cost raw materials can hope to be competitive with any one of the three listed.

The future for isoprene is certainly assured particularly as continued research and development suggest specific methods for producing improved rubbers. We are at present at the beginning of a commercial entity which will play an important role in our over-all economy in the rubber and petrochemical industries. The development and utilization of an isoprene process which will help meet the requirements will guarantee the attainment of this economic goal. Research on isoprene has not had the patriotic or national interest behind it that butadiene enjoyed during the development of our synthetic rubber program during World War II. Based on the tremendous impact on the rubber and petrochemical industries, the development of a successful process for producing isoprene will be just as dramatic.

(Editor's Note: For description of two isoprene processes see PETROLEUM REFINER, Vol. 38, No. 11, Nov. 1959, page 233 and page 263.)

About the Author

Anhorn

Dr. V. J. Anhorn is manager of organic chemical research for The Goodyear Tire and Rubber Co., Akron, Ohio. Dr. Anhorn was engaged in organic and new process research in petroleum and petrochemicals for Gulf Research & Development Co. from 1940-1953. He spent a year with Southwest Reasearch Institute as a project leader in high pressure research before going with Goodyear in 1955. Dr. Anhorn received an A.B. from Huron College in 1935 and an M.S. and Ph.D. from Purdue University in 1937 and 1940. His prime interests are in the application of statistical experiment design and bench scale techniques to process studies.

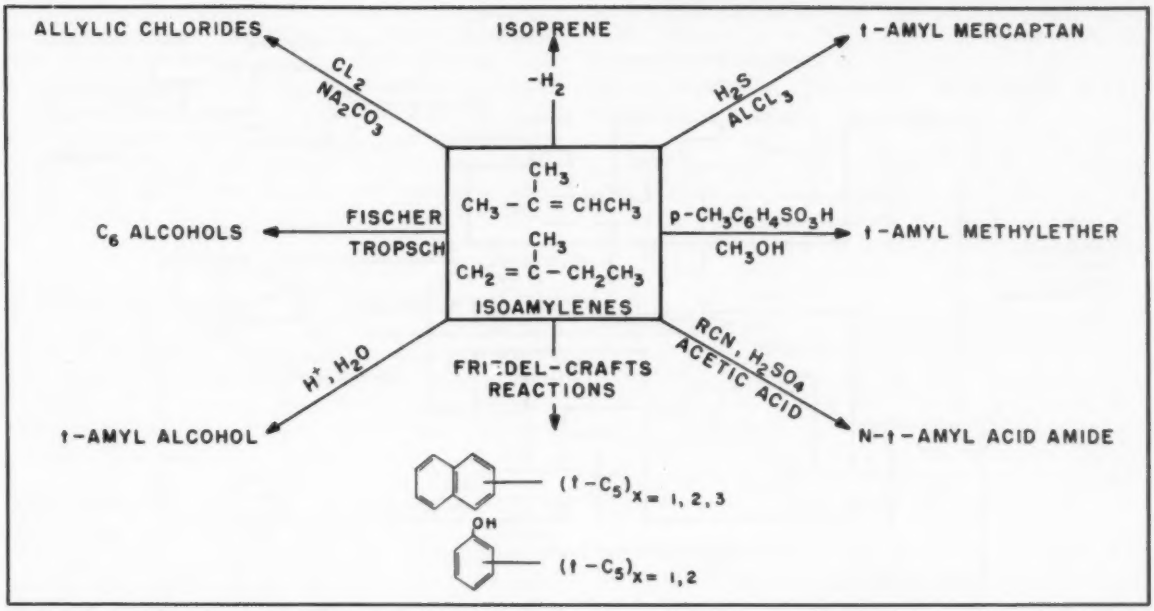

FIGURE 1—Presently the most important reaction of isoamylenes is the dehydrogenation to isoprene for synthetic natural rubber production.

New Process for Pure Isoamylenes

Here's an extraction method which retains acid strength, keeps polymer formation low, and gives isoamylenes of almost 99 percent purity

R. L. Foster, D. K. Wunderlich, S. H. Patinkin and R. A. Sanford
Sinclair Research Laboratories, Inc., Harvey, Ill.

A NEW SULFURIC ACID extraction process yielding isoamylenes in high purity, developed by Sinclair Research Laboratories, selectively removes isoamylenes from the C_5 fraction of gasoline produced by catalytic cracking. In essence, the process is one in which the close boiling C_5's admixed with isoamylenes are replaced by relatively high boiling hydrocarbons and the final separation made by an easy distillation.

Recently there has been much interest in high purity isoamylenes as basic petrochemicals. Their use as intermediates in the preparation of synthetic natural rubber, new types of plastics and a variety of new chemicals is steadily increasing. Still broader applications of high purity isoamylenes have been handicapped to date by the absence of a commercially attractive major source of supply. The new Sinclair process now can provide a large and steady reservoir of isoamylenes. This development should broaden the market for isoamylenes in known applications, and in addition, promote the development of new derivatives.

Typically, the isoamylenes separated in the process consist of 2-methyl-2-butene and 2-methyl-1-butene in a yield ratio of about 9 to 1. This isoamylene mixture is easily produced in high purity. Isomerization occurs during extraction so that the product always contains approximately the above ratio of isomers. In most applications for isoamylenes, isomer distribution will be of no consequence, the same product being yielded by both

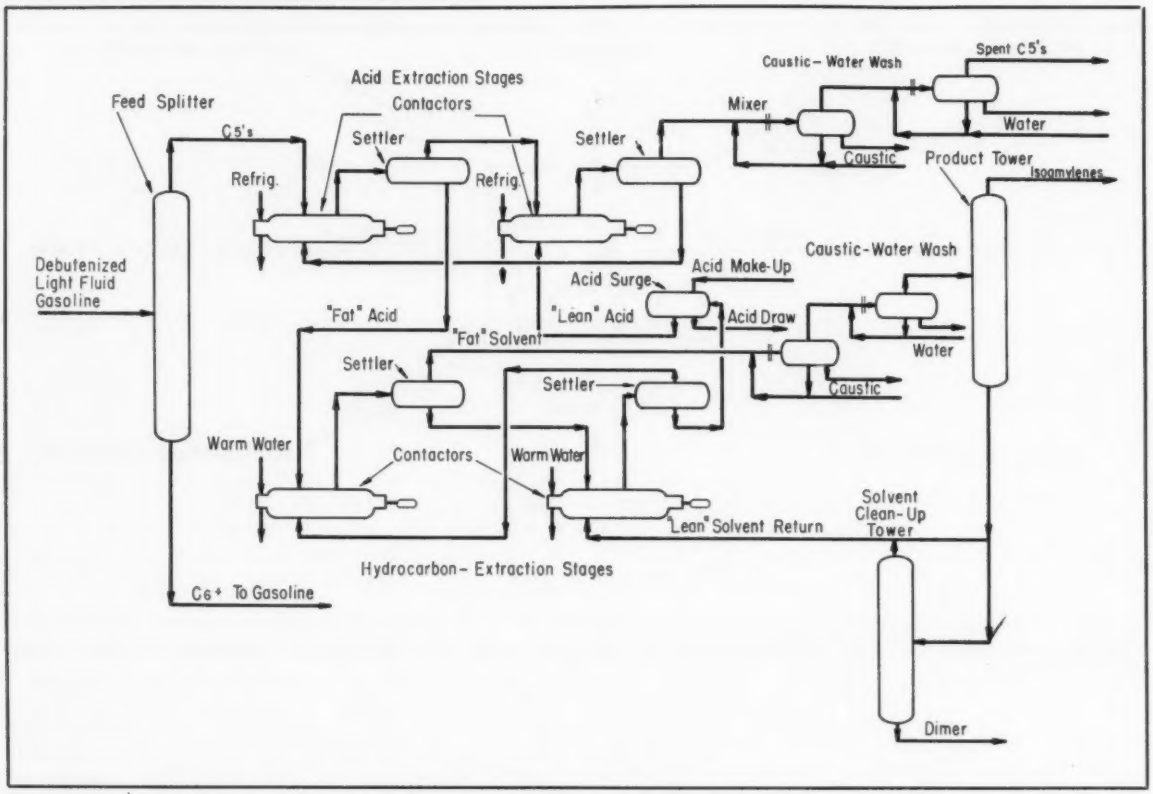

FIGURE 2—In this new isoamylene extraction process, notice that hydrocarbon solvent is used. This prevents dilution of the acid when "springing" the isoamylenes from the fat acid.

isomers. In those instances where a pure isomer is required, it can readily be obtained by fractionation of the product mixture.

Isoamylenes undergo addition and condensation reactions characteristic of tertiary olefins. These are in part illustrated in Figure 1. Presently, a major use for the isoamylenes is seen in their dehydrogenation to isoprene. The *cis*-1, 4-polyisoprene produced from this monomer is commonly called "synthetic natural rubber" and is a complete replacement for the natural product. It is already in limited commercial production and shows signs of considerable growth. The use of isoamylenes in alkylations to produce substituted phenols and naphthalenes is well known. The products find application in the anti-oxidant and detergent fields, respectively.

Isoamylenes are found in concentrations ranging from 25 to 45 percent in the C_5 fraction of gasolines from catalytic cracking. An analysis of a typical C_5 fraction from this source along with the boiling points of each component are listed in Table 1. The separation of the isoamylenes from this C_5 fraction by distillation is a difficult and thus a very costly procedure.

Sulfuric acid extraction followed by water dilution to "spring" the extracted olefins, as employed with isobutylene, could be used for the recovery of isoamylenes. However, the equilibrium distribution of isoamylenes between a hydrocarbon phase and a dilute sulfuric acid phase gives a much lower relative concentration in the acid phase than is the case at the same conditions with isobutylene. Dilute sulfuric acid extraction of isoamylenes therefore requires a higher acid to hydrocarbon ratio than does isobutylene. The reconcentration of the diluted acid is a major problem in the application of this conventional approach to the recovery of isoamylenes. The process developed by Sinclair employs a new concept for the recovery of the tertiary C_5 olefins from the "fat" acid. The very equilibrium distribution which makes necessary high acid ratios

TABLE 1. Typical C_5 Feed Analysis

	Weight, Percent	Atmospheric Boiling Point °F
C_4's	2.19	.....
Isopentane	34.74	82.13
1-Pentene	2.36	85.95
2-Methyl-1-butene	12.44	87.98
Isoprene	0.32	93.32
n-Pentane	5.57	96.93
trans-2-Pentene	11.77	97.45
cis-2-Pentene	8.01	98.80
2-Methyl-2-butene	21.60	101.34
C_6+	1.00	.....
	100.00	

for extraction, also makes feasible the reversal of the extraction. The "fat" acid phase is contacted with a relatively high boiling hydrocarbon solvent and the isoamylenes are thus extracted from the acid. Isoamylenes are recovered from the solvent by simple distillation. This method of recovering isoamylenes from the "fat" acid eliminates the need for dilution and subsequent reconcentration of the acid. Efficient removal of the isoamylenes from the feed hydrocarbon and recovery from the "fat" acid are obtained by the proper choice of the phase ratios, temperatures and number of stages in each step.

PROCESS DESCRIPTION

Pre-fractionation. Figure 2 is an illustrative schematic flow diagram of the process. Debutanized gasoline from catalytic cracking is fed to a tower in which the C_5 fraction is taken overhead. A moderate C_6 tail can be left in the C_5 concentrate since the C_6 olefins, at conditions favorable for isoamylene extraction, have low solubility in the acid.

Acid Extraction. The liquid C_5 concentrate passes to one or more mixer-settler stages in which the isoamylenes are selectively extracted from the hydrocarbon stream by 65-weight-percent sulfuric acid. The number of stages, stage temperatures, and acid to hydrocarbon ratios in particular applications are set by economic balances and, of course, depend upon the feedstock composition and the degree of recovery desired. Where more than one stage is used, countercurrent flow of acid and hydrocarbon through the cascade is practiced. The transfer of isoamylenes from the hydrocarbon phase to the acid liberates a considerable amount of heat which must be removed from the contactors. The spent C_5's from the final extraction stage are caustic and water washed and can be returned to gasoline or further processed for the recovery of other C_5 hydrocarbons.

Economic factors generally dictate temperatures in the range from 50° to 70° F in the acid extraction stages. Lower stage temperatures result in more isoamylene extraction per stage at a given acid to hydrocarbon ratio, but the increasing viscosity of the "fat" acid limits the low end of the practical temperature range. The rate at which isoamylenes are transferred to the acid phase is primarily dependent upon the degree of mixing employed. Commercially available contactors give a rapid approach to the equilibrium distribution of isoamylenes between the phases.

Since the principal impurities in the isoamylene product are other C_5 hydrocarbons that may be physically entrained in the "fat" acid phase, it is highly desirable that the effluent from the final "fat" acid stage be well settled. Although not normally required, a vacuum flash of the "fat" acid can be used to further remove entrained hydrocarbons and thus maximize purity of the final product.

Regeneration of Isoamylenes from the Acid Extract. The "fat" acid from the acid extraction stages passes to one or more mixer-settler stages in which the acid phase is contacted with a hydrocarbon solvent. The reactions which occurred in the acid extraction stages are now reversed and the isoamylenes transferred to the hydrocarbon solvent. Since this process is essentially the reverse of the acid extraction process, the transfer of isoamylenes between phases is endothermic and heat must be supplied to the contactors to hold temperature.

The "lean" acid from the hydrocarbon extraction stages is recycled to the acid extraction stages. A small part of the "lean" acid is continuously withdrawn from the system and fresh makeup added to control acid strength and prevent the buildup of trace impurities in the circulating acid stream.

Solvent Selection. Several factors bear on the selection of the solvent used. The solvent must boil far enough above the isoamylenes to make the final distillation of isoamylenes relatively simple, be inert to the acid used, and give favorable equilibrium relationships for the distribution of isoamylenes between the phases. Paraffin solvents of 6 to 10 carbon number have been found to be the most satisfactory on all points.

Polymerization. Some polymerization of isoamylenes occurs in all stages of the process in which isoamylenes are in contact with sulfuric acid. In the acid extraction stages, at the low temperatures employed, the problem of limiting this polymerization is a minor one. Since the equilibrium relationships for the transfer of isoamylenes from the acid to the hydrocarbon solvent phase are more favorable at higher temperatures, the hydrocarbon extraction stages are run at higher temperatures (up to 100° F), and therefore polymerization is more of a problem. Even in this section of the process, polymer make can be reduced to arbitrarily low values through the proper selection of solvent to acid ratio, of stage temperatures and of equipment.

The method of isoamylene and acid regeneration employed in the process has advantages over a process employing water dilution in simplicity of operation, in the lower severity of corrosion and in acid life. These advantages arise from the facts that (1) throughout the process the acid concentration is maintained close to that which gives the minimum corrosion rate on carbon steel, (2) mixtures of hydrocarbon and acid are exposed nowhere in the process to a temperature in excess of 100° F.

Solvent Fractionation and Cleanup. The solvent-isoamylene mixture from the hydrocarbon extraction stages is caustic and water washed to remove entrained acid, and then passes to a tower where the isoamylene product is taken overhead. The bulk of the tower bottoms is recycled directly to the process, but a small part of the stream is fractionated in a second tower to control polymer concentration in the hydrocarbon extractant before being returned to the process.

PILOT PLANT EXAMPLE

In the course of studying the process, a continuous integrated pilot unit was operated. This unit consisted

of a single stage of acid extraction from the feed hydrocarbon and a single stage of hydrocarbon extraction from the "fat" acid. The acid phase was recycled between stages but the hydrocarbon solvent used for extracting isoamylenes from the "fat" acid was run once through. Simple vigorously-stirred vessels were used in the mixer stages, and simple settlers giving about 20 minutes settling time were employed. Isoamylenes were stripped from the solvent by batch distillation. For periods up to several weeks the plant was run on a single acid charge. No decline in the efficiency of the acid for extraction nor other evidence of acid degradation, such as emulsion problems in the settlers, showed up in these periods.

As an example, the results obtained on a run with this apparatus are summarized in Tables 2, 3, and 4. This run, of course, does not necessarily reflect conditions to be employed in any commercial application of the process.

In this run the acid used was 65-weight-percent sulfuric acid and the solvent used to extract the isoamylenes from the acid was normal heptane.

TABLE 2. Pilot Plant Operating Conditions

	Acid Extraction Stage	Hydrocarbon Extraction Stage
Mixer Temperature	68° F	100° F
Mixer Contact Time	10 minutes	10 minutes
Settler Residence Time	20 minutes for both phases in both stages	
"Lean" Acid to Total Feed		.....
Hydrocarbon Volume Ratio	0.306	
Solvent to "Fat" Acid Volume Ratio	.....	1.62

TABLE 3. Isoamylene Concentrations at Operating Equilibrium

Stream	Weight Percent Isoamylenes
Hydrocarbon Feed	41.3
Spent Hydrocarbon	29.1
"Fat" Solvent	17.5
"Fat" Acid	24.5
"Lean" Acid	7.7

TABLE 4. Weight Percent Analyses of Various Streams*

	Feed	Spent Hydrocarbon	Product
C_4's	0.9	1.1	.....
Isopentane	25.9	31.2	0.5
Normal Pentane	7.6	9.2	0.2
1-Pentene	5.1	6.2	0.1
2-Pentene	18.6	22.5	0.3
Isoamylenes	41.3	29.1	98.9
C_6+	0.6	0.7	.....
	100.0	100.0	100.0

*In this run, a polymer make of 3-weight percent of the isoamylenes extracted was observed.

Semi-Plant Study. A study was also conducted at Stratford Engineering Corporation Laboratories in steel equipment similar to that which would be used in a commercial plant. These tests involved continuous test runs using a single acid extraction stage and a single hydrocarbon extraction stage and confirmed the commercial feasibility of the equipment and the process.

Licensing. This economically attractive new isoamylene extraction process developed at Sinclair Research Laboratories, Inc., and based on reversible extraction reactions, is being offered for licensing by the Stratford Engineering Corp. Specific designs and complete heat and material balances for particular feedstocks are available from the Stratford Engineering Corp.

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About the Authors

R. L. Foster

R. L. Foster is a research chemist with Sinclair Research Laboratories, Inc., Harvey, Ill., working in research and development in petrochemicals and petroleum processing. Foster has been in petroleum research, including petrochemicals and fuels research for eight and a half years. He holds a B.S. degree from Monmouth College and his PhD. from the University of Illinois.

D. K. Wunderlich

Donald K. Wunderlich is a project engineer with the Sinclair Research Laboratories, Inc., engaged in data correlation, research project evaluation, research program planning, and research and development program coordination. He has been with Sinclair Research for 12 years. He has a B.S. in chemical engineering from Northwestern University.

S. H. Patinkin

Seymour H. Patinkin directs a section involved in research on the combustion of fuels in internal combustion engines and in the development of fuel additives for Sinclair Research Laboratories, Inc. He has worked five years in petrochemicals and hydrocarbon conversions research. He earned his B.S. and PhD. degrees in chemistry from the Illinois Institute of Technology.

R. A. Sanford

R. A. Sanford is director of the Exploratory Division, Sinclair Research Laboratories, Inc. He supervises research in the fields of catalysis, petroleum processing and petrochemicals. He worked two years in research with the Manhattan Project at the University of Rochester, and one year on a post doctorate in chemistry at Purdue University. He has been with Sinclair Research for 11 years. He holds a B.S. in chemistry from St. Louis University and a PhD. in organic chemistry from Purdue University.

Applied Hydrocarbon Thermodynamics

Part 23: Evaluation of Vapor Fugacity and Activity Coefficients

Wayne C. Edmister
Oklahoma State University, Stillwater, Okla.

Vapor Activity Coefficient. The activity coefficient of a component in a mixture is defined here as the ratio of the fugacity coefficient of the component in the mixture to the fugacity coefficient in a pure reference state at the same temperature and pressure. This definition applies to both liquid and vapor phases. At this point, only the vapor phase is of interest, however.

The fugacity coefficient in the pure vapor state is a straightforward calculation except in the hypothetical vapor region where the component in question could not exist as a pure vapor at the temperature and pressure of the system. This is the situation for the heavier components of the equilibrium vapor. There are two basic methods of evaluating the fugacity coefficients for this hypothetical vapor state, namely: (a) extrapolating the vapor phase volumetric isotherms through the two-phase region and (b) extrapolating the vapor phase fugacity coefficient isotherms through the two-phase region. Extrapolating by equations of state might be considered partly volumetric and partly fugacity extrapolations.

Earlier Figure 18.1, was presented. This figure was prepared by extrapolating the fugacity coefficients and using some observed vapor-liquid equilibria values to aid in drawing the f/P vs P_r curves for $T_r < 1.0$.

Another extrapolation into this hypothetical vapor state can be made by use of the Edmister-Ruby[2] generalized correlations giving activity coefficients as a function of T_r, P_r, and B_r. These were shown as Figures 19.1 through 19.6. In these generalized correlations the equivalent of a pure component exists when $B_r = 1$, which makes $\Theta = T_r$.

The vapor activity coefficient from these charts will be

$$\gamma^v = \frac{(f/Py) \text{ at actual } B_r}{(f/Py) \text{ at } B_r = 1.0} \qquad (23.1)$$

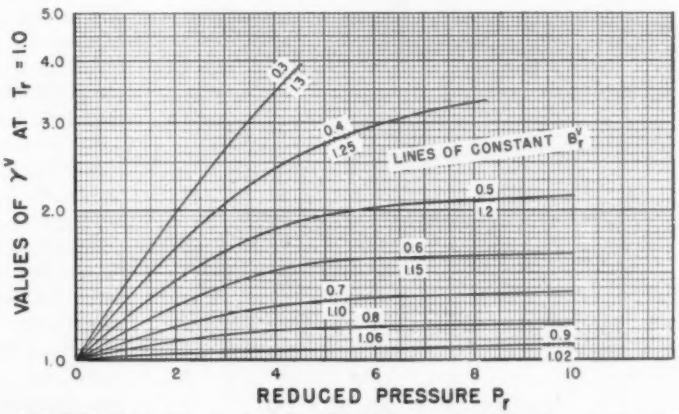

FIGURE 23.1—Vapor Activity Coefficient as a Function of P_r and B_r^V at $T_r = 1.0$.

Values of γ^V were evaluated for a range of T_r, P_r, and B_r by Equation 23.1 and readings of the fugacity coefficients from Figures 19.1 through 19.3. From these vapor phase activity coefficients, the correlation in Figure 23.1 and 23.2 was prepared. Figure 23.1 gives γ^V as a function of P_r and B_r^V for unity reduced temperature, while Figure 23.2 gives the effect of T_r on γ^V.

This γ^V correlation will be compared later with other methods of finding γ^V. Two of these methods, the Joffe and the Redlich-Kwong methods, are extensions of vapor fugacity coefficient methods.

Fugacity and Activity Coefficients by Joffe Equation. This expression for estimating the fugacity coefficient of the components of vapor mixtures is based on the following generalizations: (1) compressibility factor, Z vs P_r, and T_r, (2) fugacity coefficient vs P_r and T_r, (3) isothermal pressure correction to enthalpy, $(H - H^\circ/RT_C)$ vs P_r and T_r, and (4) pseudo critical concept of Kay, where $T_{PC} = \Sigma y_i T_{c_i}$ and $P_{PC} = \Sigma y_i P_{c_i}$. Pseudo critical temperatures and pressures are molar averages of the component critical values.

The first three of these are generalized correlations for pure components. They are applied to mixtures by the pseudo reduced (ratio of system temperature or pressure to pseudo critical values) conditions. Kay's pseudo critical concept is a convenient but not precise method of approximating mixture properties.

Besides being convenient, this "pseudo critical," "hypothetical component" method for evaluating thermodynamic properties of mixtures is fairly reliable except for extreme applications. Being of sufficient accuracy for calculating mixture densities does not guarantee that the method will be accurate in predicting "partial" properties of the component in mixtures.

While recognizing these limitations in the basis, it is of value to look at the Joffe equation, which is

$$\ln \phi_i = \ln \frac{\bar{f}_i^V}{y_i P} = \left(\ln \frac{f}{P}\right)_m + (Z-1)\left(1 - \frac{P_{c_i}}{\Sigma y_i P_{c_i}}\right) + \left(\frac{H^\circ - H}{RT_C}\right)\frac{1}{T_r}\left(1 - \frac{T_{c_i}}{\Sigma y_i T_{c_i}}\right) \qquad (23.2)$$

As pointed out above $(\ln f/P)_m$, Z, and $\Delta H/RT_C$ are properties of the mixture. They are functions of the pseudo reduced properties of the mixture. These hypothetical component properties are combined to give $\bar{f}_i^V/y_i P$ the fugacity coefficient of component "i." This combination is made by the functions of two critical constant ratios, i.e., $T_{c_i}/\Sigma y_i T_{c_i}$ and $P_{c_i}/\Sigma y_i P_{c_i}$.

Thus, $(\bar{f}_i/y_i P)$ is determined by two temperature ratios and two pressure ratios. It would appear that these four parameters should be enough to define ϕ_i. For convenient reference Equation 23.2 is rewritten.

$$\ln \phi_i = (\ln f/P)_m + F_Z F_{P_C} + F_H F_{T_C} \qquad (23.3)$$

where:

$$F_Z = (Z-1)$$

$$F_{P_C} = \left[1 - \left(\frac{P_{c_i}}{\Sigma y_i P_{c_i}}\right)\right]$$

$$F_H = \left(\frac{H^\circ - H}{RT_C}\right)\frac{1}{T_r}$$

$$F_{T_C} = \left[1 - \left(\frac{T_{c_i}}{\Sigma y_i T_{c_i}}\right)\right]$$

It is of interest to note that the Joffe Equation used two composition parameters, i.e., F_{P_C} and F_{T_C} or (P_{c_i}/P_{PC}) and $T_{c_i}/T_{PC})$ where P_{PC} and T_{PC} are the pseudo criticals of the mixture. Having two composition parameter should make this equation very effective, in spite of the limitations in the pseudo critical concept and the generalized correlations of f/P, Z and ΔH used in applying the equation. Pitzer et al.[6,7] have already shown that these properties are functions of an acentric factor in addition to reduced pressure and temperature. Adding the acentric factor as an additional parameter might improve the accuracy of the Joffe method, but it would make it more complex.

An examination of the F_{P_C} and F_{T_C} terms reveals that each of these becomes zero for a component having a critical equal to the pseudo critical. For a multicomponent mixture, therefore there can be one component for which $\phi = (f/P)_m$. Of course, F_{P_C} may be zero and F_{T_C} might be greater or less than zero, or vice versa.

Figures 23.3, 23.4, and 23.5 have been prepared for more convenient application of the Joffe Equation to the computation of the vapor fugacity. Figure 23.3 is a replot of the Lewis and Luke f/P plot given as Figure 18.1. This form is more convenient to use in

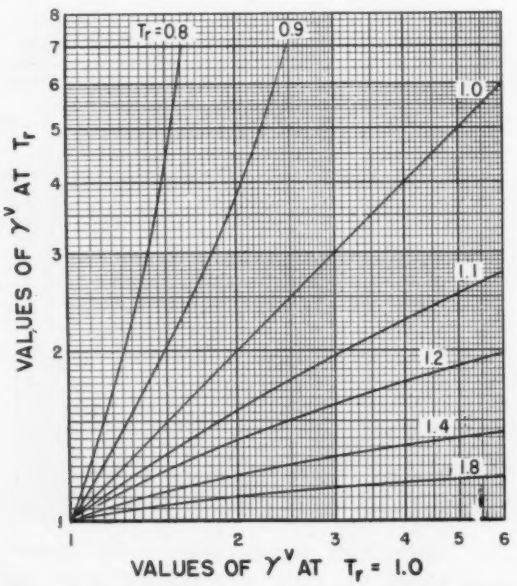

FIGURE 23.2—Effect of T_r on Vapor Activity Coefficient.

TABLE 23.1—Critical Constant Factors for Application of Redlich-Kwong Equation

	T°K	Pcatm	Tc_i/Pc_i	$Tc_i^{1.25}/Pc_i^{0.5}$
H_2	32	12.8	2.5	21.24
N_2	126.3	33.5	3.77	73.4
Methane	191	45.8	4.163	54.7
Ethylene	283	50.5	5.600	80.6
Ethane	305.3	48.2	6.335	89.7
Propylene	365	45.4	8.045	113.2
Propane	370	42.0	8.810	119.6
i-Butane	408	36.0	11.340	143.4
i-Butylene	418	39.4	10.610	140.9
l-Butylene	419.5	39.7	10.567	141.3
n-Butane	425	37.5	11.33	147.7
i-Pentane	461	32.88	14.025	172.5
n-Pentane	469.6	33.3	14.11	175.0
n-Hexane	508	29.9	17.00	201.1
n-Heptane	540	27.0	20.00	229.0
n-Octane	569	24.63	23.10	252.5
n-Nonane	596	23.5	25.38	273.2
n-Decane	619	21.8	28.40	295.5
H_2S	373.6	88.87	4.204	82.75
Benzene	562.7	48.66	11.56	179.1
Toluene	593.8	40.15	14.79	208.3

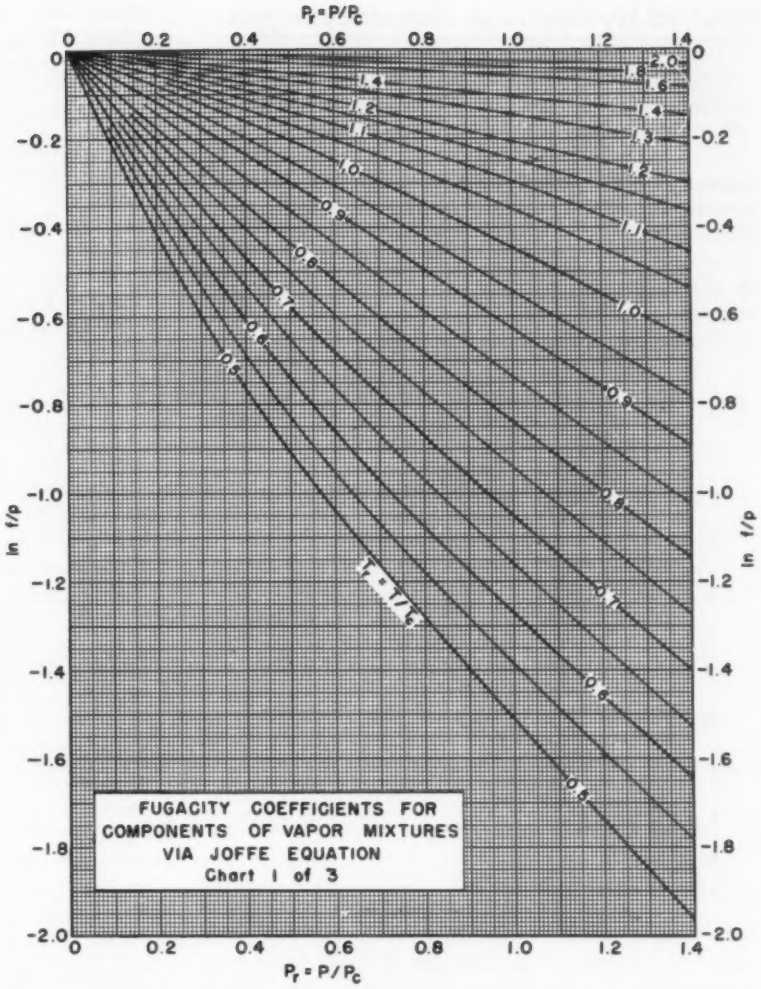

FIGURE 23.3—Fugacity coefficients for components of vapor mixtures via Joffe Equation. (Chart 1 of 3)

Equation 23.3.

Figure 23.4 is a two-parameter graphical solution for the $F_Z F_{P_C}$ term in Equation 23.3. From the intermediate scale on the left, the makeup of this chart should be obvious.

Figure 23.5 is a two-parameter graphical solution for the $F_H F_{T_C}$ term in Equation 23.3. Here likewise, the intermediate scale illustrates how the chart was prepared.

The application of this fugacity coefficient method will be illustrated later and comparisons will be made with other methods.

The Joffe Equation and Figures 23.3, 23.4, and 23.5 can be used to estimate the activity coefficient of a component in a vapor mixture. This is done by dividing the $(\bar{f}/Py)^V$ value by the f/P value, as follows:

$$\gamma_i^V = \phi_i^V / \nu_i^V \qquad (23.4)$$

where:

$\phi_i^V = (\bar{f}/Py)_i^V$ = fugacity coefficient of "i" in vapor mixture

$\nu^V = (f/P)_i^V$ = fugacity coefficient of "i" at the pure vapor state reference

In terms of Equation 23.3

$$\ln \gamma_i^V = (\ln(f/P)_m + F_Z F_{P_C} + F_H F_{T_C} - (\ln f/P)_i^V \qquad (23.5)$$

Values of γ_i^V will be found later for a few cases. Values of $(f/P)_i^V$ are found from Figure 23.3 by using the real criticals for the component in question, not the pseudo criticals. It is of interest to note that these reduced temperatures and pressures are combinations of the ratios used in evaluating the terms in Equation 23.3

$$T_{r_i} = \frac{T}{Tc_i} = \frac{(T/\Sigma y_i Tc_i)}{(Tc_i/\Sigma y_i Tc_i)}$$

and

$$P_{r_i} = \frac{P}{Pc_i} = \frac{(P/\Sigma y_i Pc_i)}{(Pc_i/\Sigma y_i Pc_i)}$$

From these combinations of T, T_{c_i}, P and P_{c_i}, it can be seen that there are four critical properties involved in obtaining ϕ or γ by Joffe's Equation.

Fugacity and Activity Coefficients by Redlich-Kwong Equation. Fugacity coefficients of vapor mixture components can also be calculated from the critical constants of the components and combinations of them by means of a simple but extraordinary equation of state proposed by Redlich and Kwong,[16] which is an expression for pressure or compressibility factor:

$$P = RT/(V-b) - a/T^{0.5}V(V+b) \qquad (23.5)$$

$$Z = \frac{V}{V-b} - \frac{a}{RT^{1.5}(V+b)} \qquad (23.6)$$

$$Z = \frac{1}{(1-h)} - \frac{A^2}{B}\left(\frac{h}{1+h}\right) \qquad (23.7)$$

where:

$$a = \frac{0.4278\,R^2T_c^{2.5}}{P_c}$$

$$b = \frac{0.0867\,RT_c}{P_c}$$

$$Z = PV/RT$$

$$A = a^{0.5}/RT^{1.25} = \frac{0.6541}{T_r^{1.25}P_c^{0.5}}$$

$$B = b/RT = \frac{0.0867}{T_rP_c}$$

$$h = \frac{BP}{Z} = \frac{b}{V}$$

$$BP = Pb/RT$$

$$A^2/B = 4.933/T_r^{1.5}$$

As written above, the R-K equation applies to a system of constant composition, i.e. a single component or a mixture. The expressions for the constants a, b, A and B apply only to single components in pure state. For mixtures the following combinations should be made:

$$A = \Sigma y_iA_i \text{ and } B = \Sigma y_iB_i$$

In the applications of interest here the A and B constants are used. It is not correct to find a and b for mixtures from average or pseudo critical values.

Fugacity coefficients for mixture components can be computed by either of two equations that have been derived from the R-K Equation of State. The first of these is best suited to solution by digital computer. It is

$$\ln \phi_i = (Z-1)\frac{B_i}{B} - \ln(Z-BP) - \frac{A^2}{B}\left[\frac{2A_i}{A} - \frac{B_i}{B}\right]\ln\left(1+\frac{BP}{Z}\right) \qquad (23.8)$$

Where: subscripts designate component values; no subscripts indicate mixture values.

The other expression for ϕ_i is more convenient for hand calculations. This expression was obtained by regrouping the terms of the previous equation so as to give an over-all fugacity coefficient for the mixture plus corrections.

$$\log \phi_i = \log \bar{\varphi} - U\left(\frac{A_i}{A} - 1\right) + W\left(\frac{B_i}{B} - 1\right) \qquad (23.9)$$

Where base 10 logarithms instead of natural logs are used. The three terms log $\bar{\varphi}$, U, and W, have been evaluated as functions of BP and A^2/B. The term $\bar{\varphi}$ is the f/P value for the mixture. Redlich-Kwong's Equation 23.9 is analogous to Joffe's Equation 23.3.

From tabulated values of ln $\bar{\varphi}$, Z, U, and W, as functions of A^2/B and BP, which were obtained from Redlich, plots were prepared for the terms in Equation 23.9. Figure 23.6 is the log $\bar{\varphi}$ vs BP and A^2/B relationship. Figure 23.7 is a two-parameter chart giving the $U(A_i/A - 1)$ values as a function of BP, A^2/B and A_i/A. Figure 23.8 is also a two-parameter chart for evaluating the $W(B_i/B - 1)$ term from BP, A^2/B and B_i/B. It will be noted that the range of A^2/B for Figure 23.6 is 0 to 10 while the ranges for Figure 23.7 and 23.8 are 0 to 5. This is to permit applying Figure 23.6 to the pure component in the hypothetical vapor reference state. Values for extending the log $\bar{\varphi}$ plot were obtained by additional calculations.

In addition to the above charts a plot of the compressibility factor vs BP and A^2/B was made from the R-K Equation. This is given as Figure 23.9.

The Redlich-Kwong Equation of State is believed to be the best two-constant equation available. Parameter for application of the R-K equation are found from the critical constants, in °K and atmospheres. For convenience these are listed in Table 23.1 for many components of interest. In addition, the ratios T_{c_i}/P_{c_i} and $T_{c_i}^{1.25}/P_{c_i}^{0.5}$ are included.

A graphical evaluation of the R-K parameters is presented in Figure 23.10. The dashed lines illustrate the procedure for using this chart, which should be a convenience for hand calculations.

Vapor activity coefficients can also be found by the R-K equation by applying Figure 23.6 twice, once to the mixture and once to the component.

Black[3] has recently developed an equation for representing vapor phase imperfections. Redlich recommends Black's equation as an improvement over his.

Benedict-Webb-Rubin Equation. This discussion would not be complete without including this eight constant equation of state, which was developed to fit both liquid and vapor phase PVT data so that fugacity coefficients could be computed for both phases. Such calculations were made by Benedict and coworkers for 12 paraffin and olefinic hydrocarbons from methane through n-heptane.

Beyond these mixtures very little has been done in applying the BWR equation of state to vapor-liquid equilibria ratio calculations. The relatively simple equations that were used in combining the constants of components in the paraffin-olefin mixtures are not adequate for mixtures of widely different types of molecules, such as mixtures of aliphatic hydrocarbons containing aromatics and light gases, e.g. hydrogen. The BWR Equation should apply to such mixtures.

These constant combination relations, which are based on an analysis of molecule interactions, are undoubtedly closer to being correct for the vapor phase than they are for the liquid phase. In addition it is possible to neglect some of the higher order terms for the vapor phase. This gives the following simplified

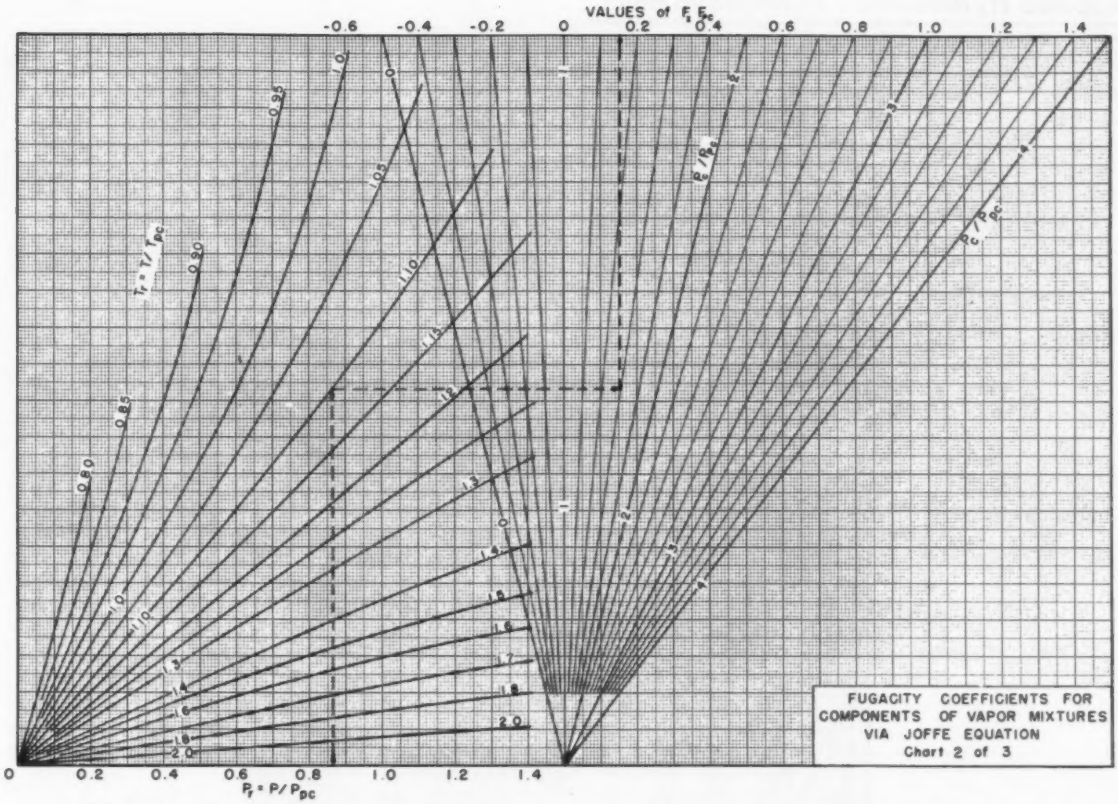
VALUES of F_1 F_{2c}
-0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1.0 1.2 1.4
$T_r = T/T_{pc}$
$P_r = P/P_{pc}$
P_c/P_{pc}
FUGACITY COEFFICIENTS FOR
COMPONENTS OF VAPOR MIXTURES
VIA JOFFE EQUATION
Chart 2 of 3

FIGURE 23.4—Fugacity coefficients for components of vapor mixtures via Joffe Equation. (Chart 2 or 3)

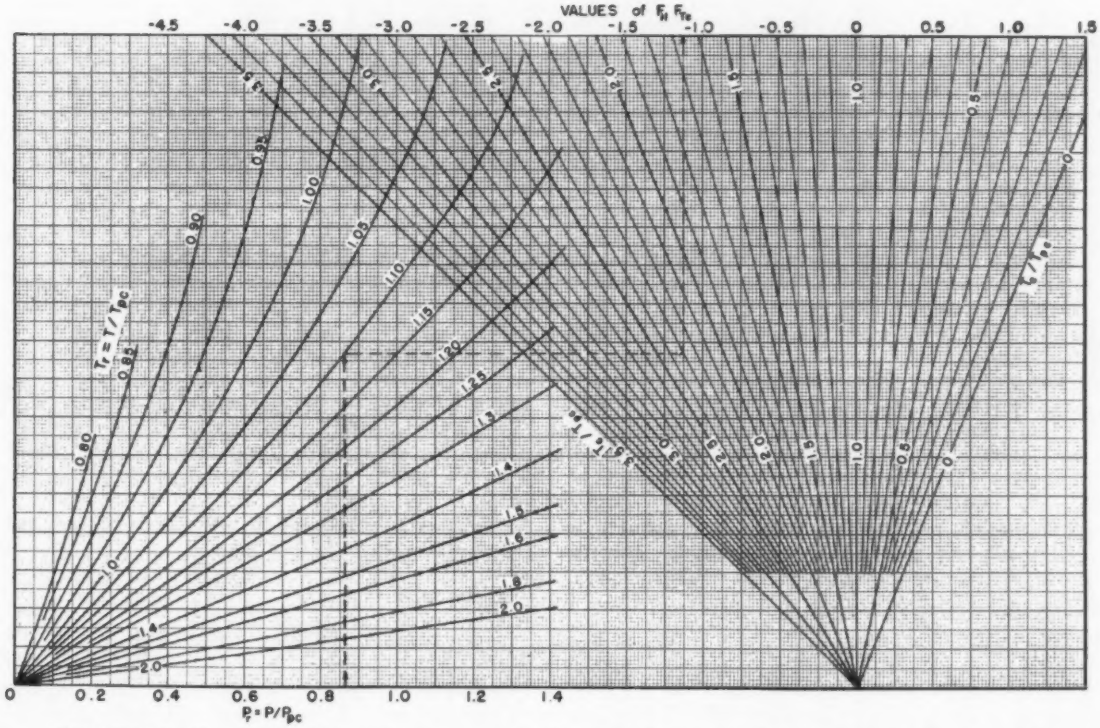

FIGURE 23.5—Fugacity coefficients for components of vapor mixtures via Joffe Equation. (Chart 3 of 3)

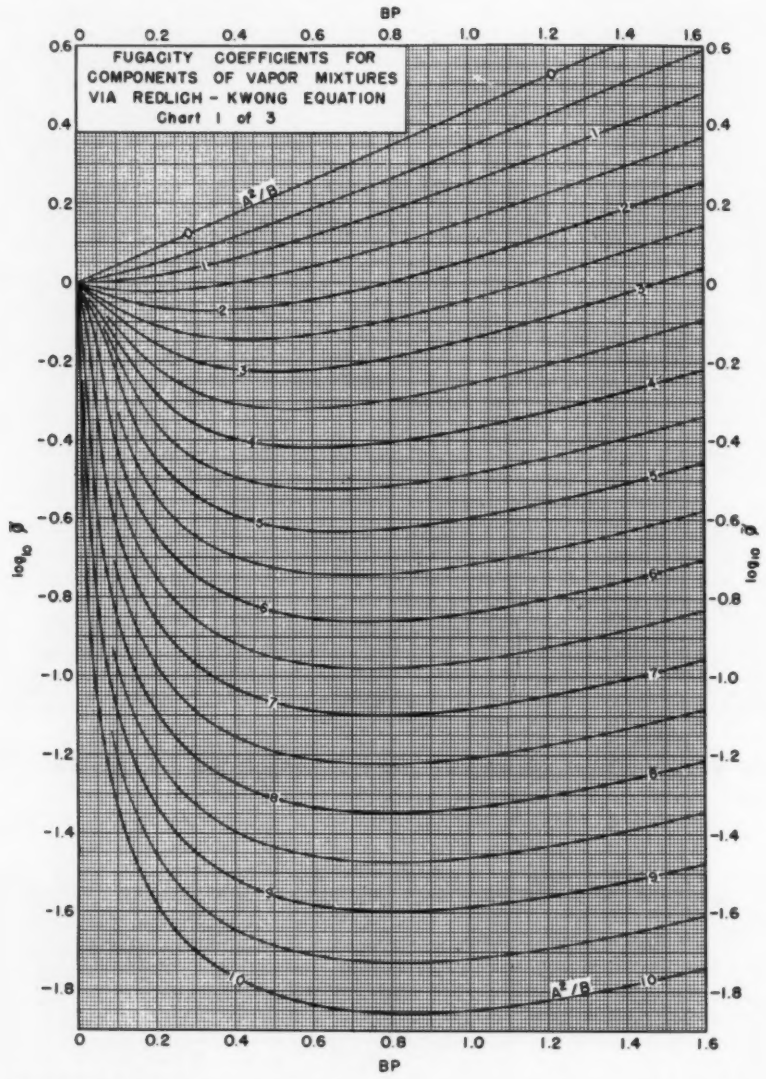

FIGURE 23.6—Fugacity coefficients for components of vapor mixtures via Redlich-Kwong Equation. (Chart 1 of 3)

BWR equation and the equation for the vapor phase fugacity coefficient.

$$P = \frac{RT}{V} + \left[B_o RT - A_o - \frac{C_o}{T^2} \right] \frac{1}{V^2} + \left[bRT - a - \frac{c}{T^2} \right] V^{1/3} \qquad (23.10)$$

This is the regular BWR Equation minus the last two terms. In Equation 23.10 the volume is used instead of density, where $1/V = d = \rho$, which was the variable in the original work. The fugacity coefficient equation based on this shortened BWR equation is

$$\ln \frac{\bar{f}_i^{\,v}}{Py_i} = \ln \frac{RT}{PV} + \frac{1}{RT} \left[(B_o + B_{o_i})\, RT - (A_o A_{o_i})^{1/2} - \frac{(C_o C_{o_i})^{1/2}}{T^2} \right] \frac{1}{V} + \frac{3}{2RT} \left[(b^2 b_i)^{1/3} - (a^2 a_i)^{1/3} - \frac{(c^2 c_i)^{1/3}}{T^2} \right] \frac{1}{V^2} \qquad (23.11)$$

where:

$$A_o = [\Sigma y_i (A_{o_i})^{1/2}]^2$$

$$B_o = \Sigma y_i B_{o_i}$$

$$C_o = [\Sigma y_i (C_{o_i})^{1/2}]^2$$

$$a = [\Sigma y_i (a_i)^{1/3}]^3$$

$$b = [\Sigma y_i (b_i)^{1/3}]^3$$

$$c = [\Sigma y_i (c_i)^{1/3}]^3$$

All but two of the eight constants are used in this

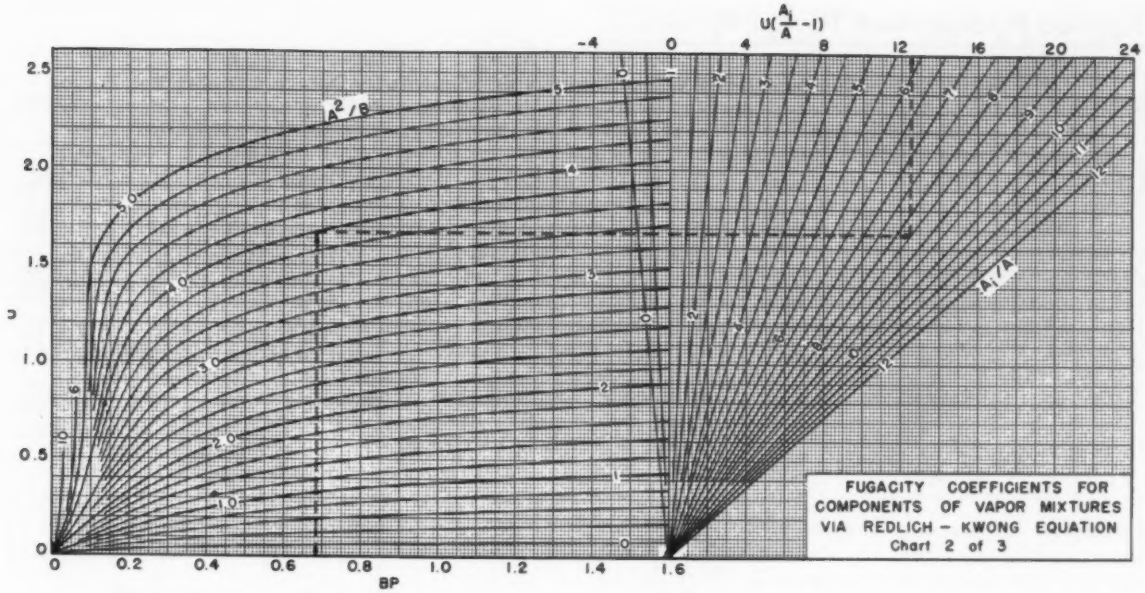

FIGURE 23.7—Fugacity coefficients for components of vapor mixtures via Redlich-Kwong Equation. (Chart 2 of 3)

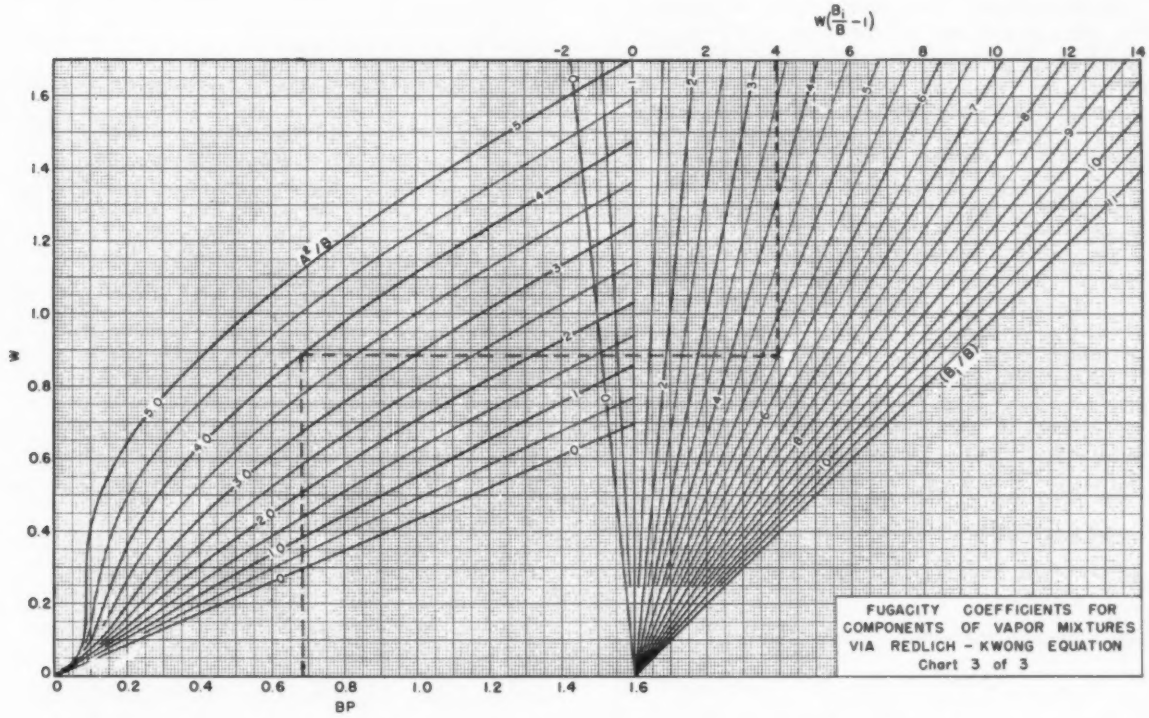

FIGURE 23.8—Fugacity coefficients for components of vapor mixtures via Redlich-Kwong Equation. (Chart 3 of 3)

simplified equation. This is to be compared with the two constants used in the Redlich-Kwong equation.

The BWR equation of state constants must be determined for each component by fitting the equation to PVT data. This has been done for 18 substances: nitrogen, methane, ethylene, ethane, propylene, propane, isobutylene, butene-1, isobutane, n-butane, isopentane, neopentane, n-pentane, n-hexane, n-heptane, n-nonane, n-decane, and benzene.

As yet no one has developed a method of finding constants for an unknown from the values of another substance and the criticals of both compounds.

TABLE 23.2—Comparison of Vapor Fugacity Coefficients By Different Methods

SOLVENT MIXTURE & CONDITIONS					SOLUTE: n-Butane						SOLUTE: n-Hexane					
					$\bar{f}/Py$ Values					γ^{V*} Values	$\bar{f}/Py$ Values					γ^{V*} Values
Temp. °F	MABP	System	m. f. Lighter	PSIA	B-W-R	E & R	R & K	Joffe	L & R		B-W-R	E & R	R & K	Joffe	L & R	
0	−210	1-2	0.6278	450.1	0.3944	0.538	0.526	0.598	0.340	1.76	0.2251	0.340	0.409	0.510	0.223	2.29
50	−210	1-3	0.7728	464.4	0.5022	0.492	0.529	0.576	0.371	1.55	0.3347	0.350	0.398	0.488	0.242	2.20
100	−210	1-4	0.8314	466.5	0.6048	0.612	0.542	0.677	0.428	1.58	0.4573	0.455	0.489	0.591	0.270	2.19
200	−180	1-6	0.8097	457.5	0.7038	0.702	0.723	0.770	0.560	1.37	0.5599	0.595	0.593	0.696	0.356	1.95
300	−180	1-7	0.7032	456.8	0.7609	0.809	0.658	0.810	0.698	1.16	0.6136	0.630	0.631	0.680	0.450	1.51
400	90	1-6	0.1585	449.9	0.8792	0.846	1.00	0.769	0.810	0.95	0.5808	0.610	0.610	0.591	0.565	1.05
0	−255	1-5	0.9891	901.0	0.2546	0.280	0.239	0.324	0.152	3.13	0.1269	0.100	0.147	0.250	0.073	3.42
50	−240	1-3	0.9122	879.1	0.3504	0.325	0.358	0.432	0.190	2.27	0.2046	0.180	0.227	0.333	0.099	3.33
100	−150	1-2	0.1710	900.3	0.2170	0.200	0.224	0.270	0.224	1.21	0.0803	0.080	0.118	0.172	0.117	1.47
200	−150	1-4	0.6245	867.2	0.4695	0.458	0.452	0.552	0.334	1.65	0.2888	0.280	0.326	0.420	0.170	2.47
300	− 90	1-6	0.5926	801.7	0 5858	0 596	0 599	0.648	0.505	1.28	0.3697	0.380	0.415	0.514	0.260	1.98
400	30	1-6	0.3032	818.9	0.6905	0.688	0.829	0.658	0.649	1.02	0.3884	0.440	0.394	0.444	0.345	1.29

* By Equation 23.5.

Examples. As illustrations of the above methods, the vapor fugacity coefficient of n-hexane at infinite dilution in a mixture of methane-pentane (98.91 percent methane, 1.09 percent pentane) will be calculated.

These calculations were made with the basic charts from which Figure 23.1 through 23.8 were prepared.

Redlich-Kwong. The value of f/Py for n-hexane in the same system and at the same conditions will be found by this method, using the charts for log φ, U, and W.

First, evaluate constants for methane and n-pentane:

$$A_{c_1} = 0.6541\,(343.2)^{1.25}/(459.7)^{1.25}(673)^{0.5} = 0.0163$$

$$B_{c_1} = 0.0867(343.2)/(459.7)(673) = 0.0000962$$

$$A_{c_5} = 0.6541(845.6)^{1.25}/(459.7)^{1.25}(489.5)^{0.5} = 0.0641$$

$$B_{c_5} = 0.0867(845.6)/(459.7)(489.5) = 0.0003255$$

Now find constants for the solvent mixture:

$$A = (0.9891)(0.0163) + (0.0109)(0.0641) = 0.0168$$

$$B = (0.9891)(0.0000962) + (0.0109)(0.0003255) = 0.00009875$$

$$A^2/B = (0.0168)^2/(0.00009875) = 2.86$$

$$BP = (0.00009875)(901) = 0.089$$

From plots find

$$\log \varphi = -0.071$$

$$U = 0.272$$

$$W = 0.057$$

For n-hexane, the solute (infinite dilution)

$$A_1 = \frac{0.6541}{(439.7)^{0.5}}\left(\frac{914.2}{459.7}\right)^{1.25} = 0.0733$$

$$B_1 = \frac{0.0867}{439.7}\left(\frac{914.2}{459.7}\right) = 0.000392$$

The fugacity coefficient of n-hexane in the vapor mixture of methane and n-pentane may now be calculated:

$$\log \frac{\bar{f}^V}{Py} = \log \varphi - u\left(\frac{A_1}{A} - 1\right) + W\left(\frac{B_1}{B} - 1\right) \qquad (23.9)$$

$$= -0.071 - 0.272\left(\frac{0.0738}{0.0168} - 1\right) + 0.057\left(\frac{0.000392}{0.00009875} - 1\right)$$

$$= -0.071 - 0.916 + 0.169 = -0.818$$

$$\bar{f}^V/Py = 0.152$$

Joffe Equation. The value of $\bar{f}/Py$ for n-hexane in the above mixture will next be computed by the use of the Z, f/P and $\Delta H/T_c$ charts.

Pseudo reduced conditions:

$$T_{Pc} = \Sigma y_i T_{c_i} = (0.9891)(343.2) + (0.0109)(845.6) = 348.7$$

$$T_{Pr} = \frac{459.7}{348.7} = 1.32$$

$$P_{Pc} = \Sigma y_i P_{c_i} = (0.9891)(673) + (0.0109)(489.5) = 671.0$$

$$P_{Pr} = \frac{901}{671} = 1.34$$

From charts read $(f/P)_m$, Z and $\Delta H/T_c$ for the mixture:

$$(f/P)_m = 0.832;\ \ln(f/P)_m = -0.1837$$

$$Z = 0.810;\ (Z - 1) = -0.190$$

$$\frac{\Delta H}{T_c} = -1.85;\ \frac{-\Delta H}{RT_c}\left(\frac{1}{T_{Pr}}\right) = +0.705$$

Calculate temperature and pressure terms for the solute, n-hexane

$$\left(1 - \frac{T_{c_i}}{T_{Pc}}\right) = \left(1 - \frac{914.2}{348.7}\right) = -1.62$$

$$\left(1 - \frac{P_{c_i}}{P_{Pc}}\right) = \left(1 - \frac{439.7}{671}\right) = +0.345$$

Now combine to find ln $(\bar{f}/Py)$ via Equation 23.3.

$$\ln(\bar{f}/Py) = -0.1837 - (0.190)(0.345) - (0.705)(1.62)$$

$$= -0.1837 - 0.0654 - 1.143 = -1.292$$

$$(\bar{f}_i/Py_i) = 0.248$$

Lewis and Randall. The L-R fugacity rule states:

$$\bar{f}_i^V = y_i f_i^V,$$

from which

$$\bar{f}_i^V/Py_i = f_i^V/P$$

Reduced conditions for n-hexane

$$T_r = \frac{459.7}{914.2} = 0.504$$

$$P_r = \frac{901}{439.7} = 2.05$$

From Figure 18.1 f/P = 0.073.

Activity Coefficient. From the values of the Joffe and L-R calculations the activity coefficient of the n-hexane in the mixture at the infinite dilution is

$$\gamma_1^V = \frac{0.248}{0.073} = 3.42$$

Comparisons of Results. Vapor fugacity coefficients for n-butane and n-hexane in different hydrocarbon mixture solvents at different temperatures and pressures were computed by five different methods. The resulting $\bar{f}/Py$ values are given in Table 23.2.

The systems and the BWR $\bar{f}/Py$ values were taken from the original work.[1] The E-R $\bar{f}/Py$ values are from the generalizations Edmister and Ruby[2] made of the BWR results. The R-K $\bar{f}/Py$ values were computed by the Redlich and Kwong equation of state by using plots of the intermediate functions as illustrated. The "Joffe" $\bar{f}/Py$ values were computed by Equation 23.3.

From these few results, it is difficult to reach definite

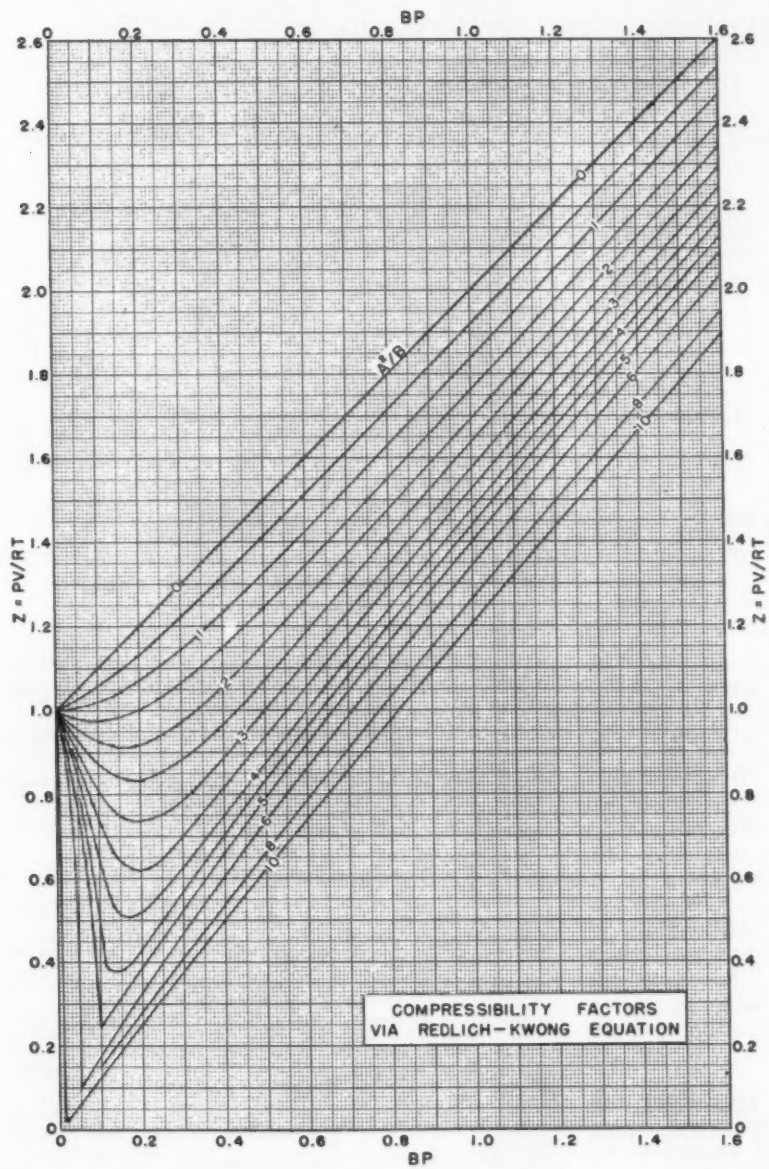

FIGURE 23.9—Compressibility Factors via Redlich-Kwong Equation.

TABLE 23.3—Comparison of Estimated Activity Coefficients By Two Methods

	n-Butane		n-Hexane	
Temperature °F.	300	400	300	400
T_r	0.994	1.127	0.831	0.941
MABP °F.	−180	+90	−180	+90
BV_r	0.570	1.12	0.552	0.893
Pressure PSIA	456.8	449.9	456.8	449.9
P_r	0.828	0.817	1.04	1.02
Activity Coefficient, γ^V				
Method I	1.176	1.075	1.45	1.050
Method II	1.160	0.960	1.51	1.050
MABP °F.	−90	+30	−90	+30
BV_r	0.754	0.998	0.601	0.796
Pressure PSIA	801.7	818.9	801.7	818.9
P_r	1.457	1.488	1.82	1.86
Activity Coefficient, γ^V				
Method I	1.100	1.000	1.82	1.095
Method II	1.283	1.014	1.98	1.290

Method I: $\gamma^V = \dfrac{(f/Py) \text{ at actual Br}}{(f/Py) \text{ at } B_r = 1.0}$ (equation 23.1)

Method II: $\ln \gamma^{V_1} = (\ln f/P)_m + F_Z F_{PC} + F_H F_{TC} - (\ln (f/P)^{V_i}$ (equation 23.5)

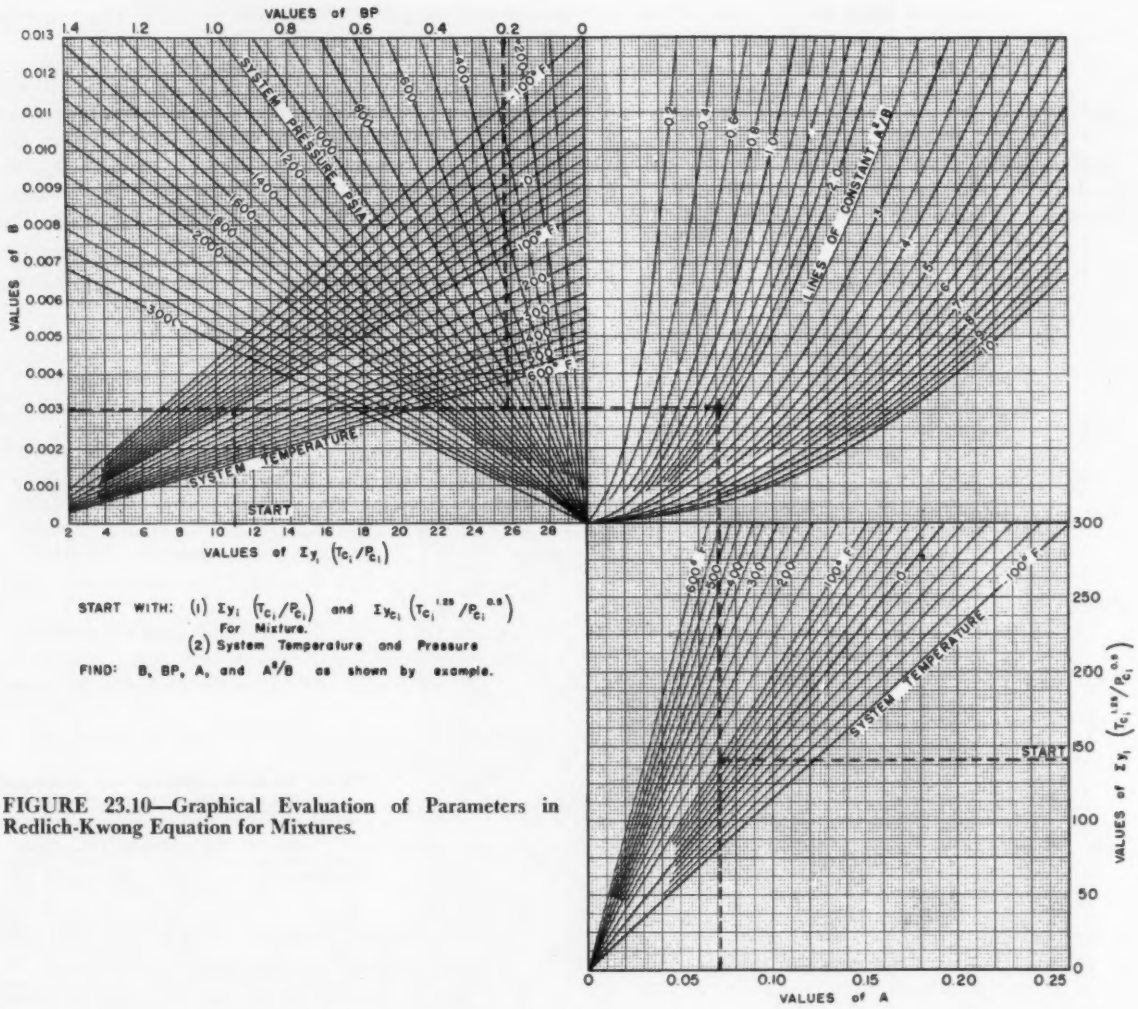
VALUES of BP
VALUES of B
SYSTEM PRESSURE, PSIA
LINES OF CONSTANT A²/B
SYSTEM TEMPERATURE
START
VALUES of Σy_i (T_ci/P_ci)
VALUES of A
START WITH: (1) Σy_i (T_ci/P_ci) and Σy_ci (T_ci^1.28/P_ci^0.8) For Mixture.
(2) System Temperature and Pressure
FIND: B, BP, A, and A²/B as shown by example.

FIGURE 23.10—Graphical Evaluation of Parameters in Redlich-Kwong Equation for Mixtures.

conclusions about these methods, except: the L-R values are generally lower than the BWR values for both hydrocarbons and the Joffe values are high for n-hexane. Being a generalization of the BWR results, the E-R values should agree with the BWR $\overline{f}/Py$ values fairly well. The absence of uniformity in these deviations may be due to the smoothing that occurred in developing the generalized correlation.

Values of γ^V via the Joffe Equation are given in Table 23.2 for each point. The magnitude of these γ^V values indicates large deviations from ideal mixtures.

Similar vapor phase activity coefficients were computed for a few points by using the E-R correlations. In this case, γ^V is the ratio of f/Py at actual B_r^V value to the f/Py at $B_r^V = 1.0$. These are compared with the Joffe - L-R γ^V values in Table 23.3.

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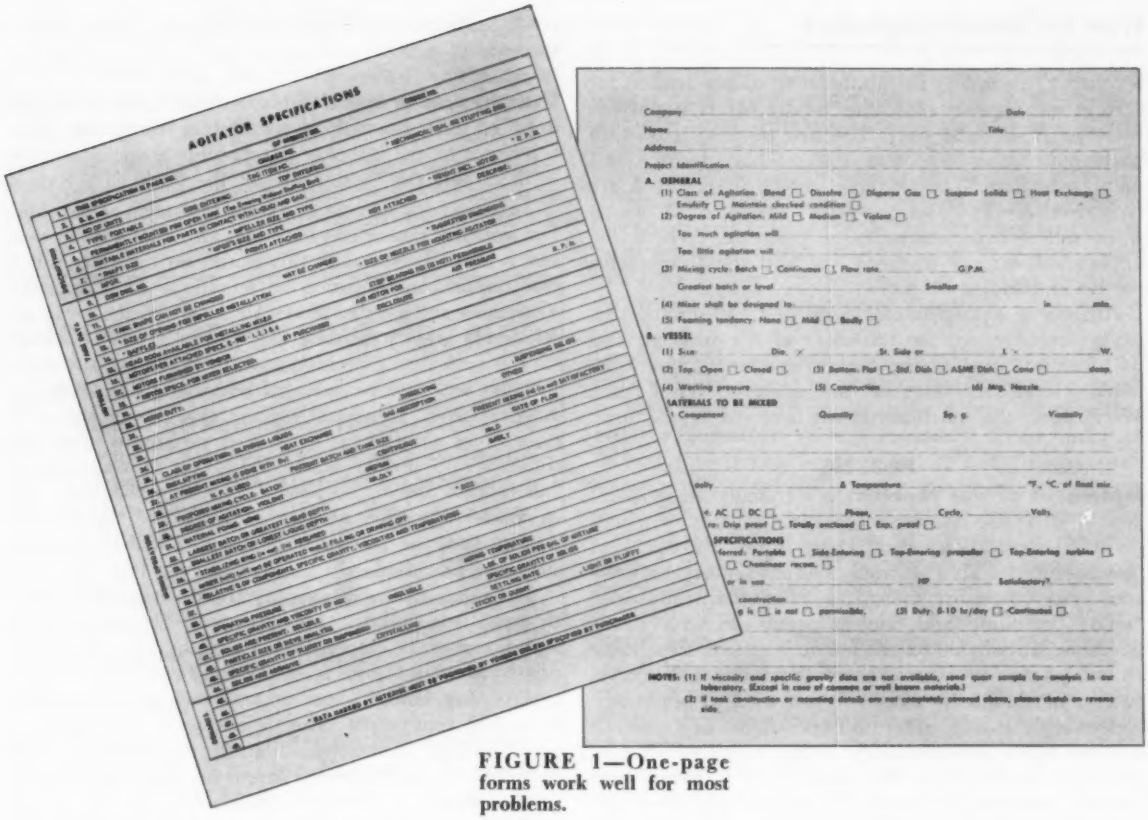
AGITATOR SPECIFICATIONS
Company
Name
Address
Project Identification
A. GENERAL
B. VESSEL
MATERIALS TO BE MIXED
SPECIFICATIONS
NOTES: (1) If viscosity and specific gravity data are not available, send quart sample for analysis in our laboratory. (Except in case of common or well known materials.)
(2) If tank construction or mounting details are not completely covered above, please sketch on reverse side.

FIGURE 1—One-page forms work well for most problems.

How to Specify Agitators

Agitator specifications are often ambiguous and require assumptions and interpretations on the part of the vendor that may vary widely

Robert L. Bates
Chemineer, Inc., Dayton, Ohio

A 10 PERCENT SAVING is a reliable estimate of the probable reduction in first costs through the writing of a good agitator inquiry or specification. Further, the beneficial effect on installation costs, performance and maintenance could easily double this saving.

Impeller type fluid agitators are particularly susceptible to tangible cost improvement, essentially because of the drastic effect on design and cost of an apparently minor change in requirement. Most users have been exposed to the harrowing experience of trying to analyze responses to an inquiry which vary in recommendation over a horsepower range of several hundred percent. Partially, the blame in such a situation must rest with the state of technology of fluid agitation. But equally at fault is usually the inquiry—ambiguous or missing data require assumptions on the part of the vendor and the interpretation can vary widely from one to another.

Most of the space here will be devoted to a study of the factors which are peculiar to an agitation application. In probably no other area of process equipment is so much miscellaneous data required. Some advance thought by the project engineer and equipment buyer, based on knowledge of a few critical areas, will yield many dividends.

Standard Data Sheets. A variety of standard data sheets have evolved and most of them do a reasonable job of covering all aspects of a problem. Very common though are the user-designed sheets which attempt to serve several purposes: transmittal of data to the vendor;

a company record of the application; and a request for certain information from the vendor. It is impossible to serve all of these well! The first purpose is of such paramount importance that a single page form is just barely adequate. The examples shown in Figure 1 are typical vendor and user one-page standard forms which work well for the majority of problems. Where the application is more involved, the additional comments are better handled by prose.

Analysis of a problem can be divided into three design categories: *Process,* the statement of the problem and the chemical engineering data; *Installation,* the functional characteristics of the agitator, vessel, etc.; *Mechanical,* the machine design involved in the unit.

PROCESS

Statement of the problem is seemingly an innocent need—but is the one area where the greatest potential for misinterpretation exists. There is no "yardstick" of performance for fluid agitation that has universal acceptance and common meaning. The frequently used "mild," "medium" and "violent" terms can involve considerable latitude in translation to practice, depending on the particular experience of the individual. Fortunately, an agitator is usually a tool used to implement performance of some other unit operation—which means that the index of performance in that field can serve as a unit of measure here. For example, if a desired heat transfer coefficient is known, it is an ideal way to dictate performance (provided, of course, it is accompanied by full data of the type familiarly required for heat transfer calculations).

One point of interest on blending problems should be mentioned. Time for a complete blend is the logical index but in filling operations it is quite important to indicate the actual time available after all components are in the tank. An obvious but oft-forgotten method of relating the process need is the use of a similar installation. Any qualitative or quantitative data that you can pass along will help shape and refine the recommendation.

Most vendors of agitators maintain a laboratory for sample testing and for model study of specific applications. It should be noted though that this service and, for that matter, the general facilities of the equipment manufacturers recognize the economic "facts of life" and are designed for short-term studies of agitation problems. It is not their place to do involved evaluation for optimum overall design or to study the variables which are not directly related to agitation. If you intend pilot plant work in your own facility, do give full consideration to the techniques necessary for proper evaluation of the agitation variables. Equipment manufacturers are generally willing and well prepared to assist you in such a study.

The physical properties of the fluid are fundamental items of data, not only in establishing the power characteristics of the impeller but possibly more important, in describing the "resistance" of the fluids to agitation.

The need for specific gravity information is two-fold. For impeller power consumption, an average fluid density is needed. Normally this causes no difficulty but it can require amplification in situations such as solids suspension and gas dispersion. In the latter, the great difference in gravity between the "gassed" and "ungassed" state is such that a decision must be made as to whether the unit will ever be operated with the gas not flowing. Knowledge of individual specific gravities of the components of multiphase systems is important since the difference in density is the indication of resistance to full motion and homogeneity. This is particularly true in solids suspension applications where the particle density (not the powder bulk density) and the particle size must be stated.

The ramifications of viscosity are too many and varied to treat here but the importance of this property in agitation must be emphasized. The frequency with which non-Newtonian liquids is encountered requires examination of any liquid whose apparent viscosity is greater than 100 centipoises. The easiest way to evaluate a pseudoplastic, thixotropic, dilatant, or rheopectic fluid is by use of a rotational viscometer. Data at different rates of shear, via alternate spindle diameters or speeds, can be tabulated for transmittal or may be represented on a log-log plot such as Figure 2. In a plot of viscosity vs. some shear index, such as spindle tip speed, the deviation of the slope from zero is the extent of non-Newtonianism.

A quantitative indication of foaming tendency is usually difficult to provide, but an attempt should be made to be realistic. Surprisingly few liquids are sensitive to agitation, per se. Usually, the precaution of minimum surface turbulence by good impeller submergence is sufficient to cope with this problem.

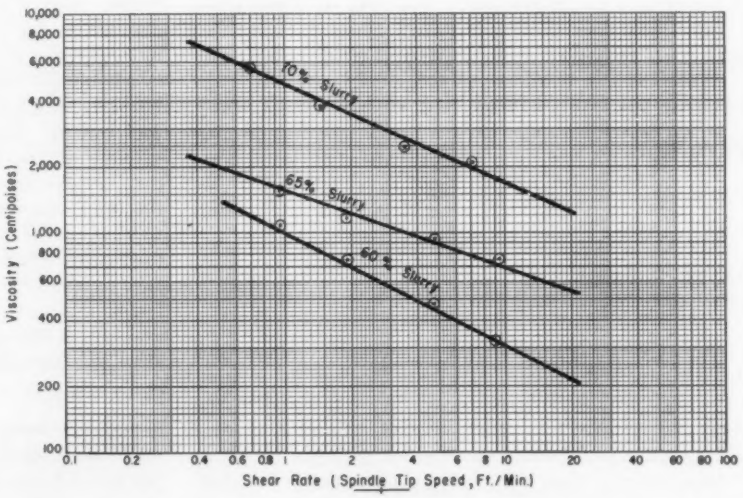

FIGURE 2—Deviation of slope from zero is extent of non-Newtonianism.

INSTALLATION

Installation would seem to be a subject to consider after the machine is received—but not if you desire to minimize cost! Here are a few things to keep in mind when you design for, specify, and evaluate an agitator.

The vessel design is the first thing that comes to mind. Be sure to state whether the tank exists or if it can be modified to enhance agitator design. Abortion of the agitator mounting flange to mate with a specified nozzle—or a special shaft design to handle an unusual geometry—can require expensive modification of a standard design. Elimination of swirl is a need to be contemplated in vessel design. Unless the viscosity is high, it is impossible to invest the required power and to develop the proper flow pattern without baffles or an off-center installation. Design data on this subject appear in the literature; or may be solicited from the equipment manufacturer. Other areas in which you can and should solicit the vendor's recommendation are tank geometry, and top-head design for drive mounting.

Liquid Level. Specification of the minimum liquid level to be agitated should be examined to be sure it is realistic. The shaft design and impeller system are very definitely a function of this requirement. By indirectly dictating such features as multiple impellers, lower speed, an oversized shaft, and a steady bearing, the cost of an agitator can easily be increased by 30 to 40 percent. In the same vein, if no draw-down of the batch through the impeller will occur, this knowledge will aid greatly in creating the most economical design.

Headroom. While you are surveying the potential installation, check the headroom available for installing and mounting the agitator drive. Keep in mind that vertical drives are less expensive than right angle styles. If headroom is low and cannot be improved, pass this information along. Figure 3 is an example of some penalties accruing from lack of such foresight. Not only did the tank have to be modified to get the drive under the beam and the belt guard burned out for maintenance access, but the variable speed handwheel is in a very cramped location.

Manway. The manway or largest opening available for inserting the impeller should be stated. Aside from fractional horsepower sizes, most agitators have standard mounting flanges for nozzles smaller than the impeller diameter.

MECHANICAL DESIGN

Here, it is especially important to know whereof you specify—which areas of design are proprietary but not critical; what is standard; what features influence cost most. Again, there are some comments particularly applying to agitation equipment.

Agitator Type. Given a free hand, the designer's selection of agitator type for a given application is often a clear-cut choice. But the borderline cases are frequent, particularly in tanks in the 1,000 to 5,000 gallon range. Here the decision between propeller and turbine types really should hinge on such agents as: desired life span; available funds; stability of the process. Only the user is in a position to evaluate these factors—which is why most data sheets have a section for indication of "type preferred."

Style and Number of Impellers. Try to leave the choice of style and number of impellers to the equipment manufacturer. His experience in this area should yield the most effective and generally the most economi-

Steps in Specifying Agitators

State The Problem

- **Kind of Agitation: Blend, Dissolve, Suspend Solids, Heat Exchange Emulsify, Gas Absorption, Other**
- **How Much Agitation: Mild, Medium, Violent**
- **Fluid Properties: Specific Gravity, Viscosity, Foaming Tendency (None, Mild, Badly), Mixing Temp., Percent of Components**

Installation

- **Vessel: Size, Top and Bottom Geometry, Working Pressure, Vertical or Right Angle Drive**
- **Liquid Level: Minimum encountered, drawdown**
- **Headroom: Clearance above top of vessel**
- **Manway: Largest opening to insert impeller**

Mechanical Design

- **Agitator Type: Propeller or Turbine Type**
- **Impellers: Number Blades, Design Type, Attachment—Usually left to choice of manufacturer**
- **Shaft Support: May give deflection and critical frequency but leave support to manufacturer**
- **Shaft Seal: State your plant's preference, Stuffing Box or Mechanical Seal**
- **Service Factor: Class I—8 to 10 hours per day, Class II—24 Hours per day**
- **Motor Enclosure: Drip Proof, Totally Enclosed, Explosion Proof**
- **Current Characteristics: Volts, Amps., Phase, Cycle**
- **Materials of Construction: Be sure you really need high corrosion resistant alloys.**

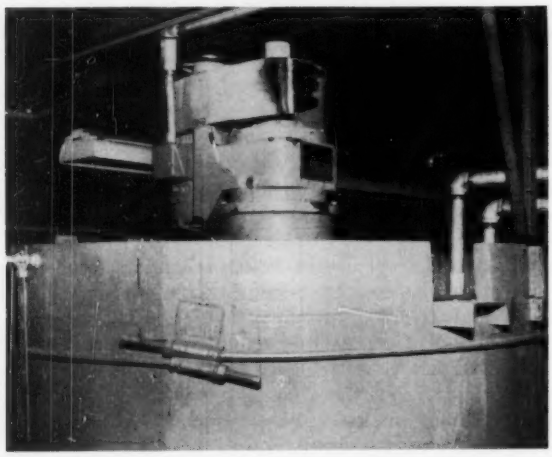

FIGURE 3—Low headroom meant cutting this tank to install the agitator drive. Note too that belt guard had to be burned for maintenance.

cal design. The number of impeller blades, blade design, and method of attachment are some of the variables possible in impeller construction—but they generally affect performance only in a minor way.

Shaft Support. The machine design involved in supporting the agitator shaft can be and is of several types but selection should be the prerogative of the equipment manufacturer—as long as it satisfies the deflection and critical frequency requirements. You may wish to place values on these operating characteristics but you should also expect or demand that the manufacturer automatically evaluate these in his selection of equipment. The possible need for a stabilizer ring or a steady bearing will result from such an appraisal.

Shaft Seal. In the realm of shaft seal design, most users have a clear-cut idea of the relative merits of stuffing boxes and mechanical seals, insofar as their own plant operation is concerned. The unique requirement in agitator design is the prevalent need to perform maintenance on the closure without disruption of the installation. On side entering agitators a shut-off feature is obtainable which permits repacking or seal replacement with a full head of liquid in the tank. On top entering turbine agitators the need is a mechanical seal assembly which can be replaced without complete dismantling of the drive—and occasionally, with the tank pressurized. These features add appreciably to agitator cost and if not needed construction will be simplified and cost reduced.

Service factors relating to the drive gearing are an indication of mechanical safety factor but most agitator installations entail a uniform load and only the duration of operation need be considered. Eight to ten hours per day usage is considered Class I and twenty-four hours per day requires a Class II rating. In some instances there is a difference in actual gearing used for a Class II rating, which will show up in the demand for a larger gear box. But just as often, it is the same unit for both ratings and you simply pay for an "insurance policy." It should be realized that the only issue at stake here is the life of the unit drive and in some cases a Class II specification would be a waste of money.

Motors and Materials of Construction. Such obvious requirements as motor enclosure, motor current characteristics and material of construction are seldom omitted but the latter specification often should be expanded upon. In many cases, parts exposed to the vapor can be less corrosion resistant than those "wetted." This would apply to mounting flange facing, exposed couplings, etc. Still on material of construction, remember that the ELC (extra low carbon) grades of stainless steel are generally required only for welded components and also that solution annealing is often an economical substitute. The need for this comment stems from the fact that low-carbon grades of alloys are not readily available in the structural forms used in shaft and impeller assemblies.

Standardization. As might be expected, standardization has not yet made much of an appearance in agitators. While such an item as mounting flange size follows a pattern of torque in a given type of unit, the shift in size doesn't always occur at the same place with different manufacturers. There is even indecision as to whether bolt holes should straddle or occur on the flange centerlines. Thus, final specification of mounting, space consumption, and similar features would best be deferred until a specific vendor has been selected.

Design Evaluation. The review and selection of offered designs cannot be made on the basis of horsepower alone —equally important is the impeller-speed combination. Within limits, a given mixing application may be viewed as a constant torque requirement and a 10 hp., 100 rpm agitator may be no more effective than a 7½ hp, 84 rpm design.

In retrospect, it would seem that I have discussed "How To Inquiry An Agitator" rather than how to specify one. Significantly, elaborate and complete specifications can work to a disadvantage in your attempt to obtain a "bargain." Do provide complete data but, where possible, give the equipment manufacturer as much latitude as possible.

About The Author

Robert L. Bates is vice president and technical director of Chemineer, Inc. of Dayton, Ohio. He received his bachelor of chemical engineering degree from Ohio State University in 1948, and the degree of chemical engineer in 1958. Mr. Bates has been associated, industrially, with Monsanto Chemical Company, the Atomic Energy Commission, and International Engineering Inc. He is a member of the American Institute of Chemical Engineers, the American Chemical Society, the American Oil Chemists Society, the Engineers Club of Dayton, and is a registered Professional Engineer (Ohio). His specialty is fluid agitation and he has a number of publications and patents in the field.

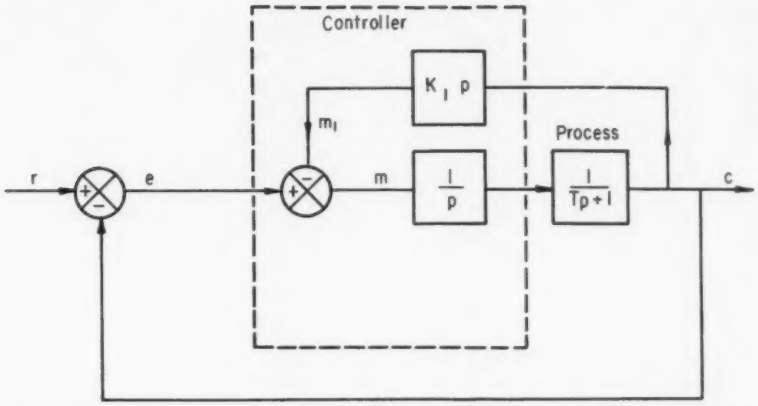

FIGURE 158—This process control system contains a feedback loop giving derivative action in addition to the regular feedback loop.

PART 23
Automation Today

Here are two relatively simple examples of nonlinear control systems. They illustrate how you can handle this type of control problem

Theodore J. Williams and Verlin A. Lauher
Monsanto Chemical Company, St. Louis

IN PART 22 of this series we presented some of the basic principles of nonlinear control theory, outlined some of the possible methods of solution of nonlinear control problems, and introduced the phase plane method of plotting the responses of such systems.

Now we will discuss two relatively simple examples of nonlinear control to further illustrate the theory and applications involved. Future parts will treat other more complicated and possibly more directly useful nonlinear devices.

AN EXAMPLE OF NONLINEAR CONTROL

Figure 158 presents the block diagram of a possible process control system containing, in addition to the regular feedback loop, another loop giving derivative action to the controller as well.

One could write the differential equation for this system as follows:

$$r - c = e \tag{1}$$

$$e - m_1 = m \tag{2}$$

$$m_1 = K_1 pc = K_1 \frac{dc}{dt} \tag{3}$$

$$c = \left(\frac{1}{p}\right)\left(\frac{1}{Tp+1}\right)(m) \tag{4}$$

$$m = p\,(Tp+1)\,c = T\frac{d^2c}{dt^2} + \frac{dc}{dt} \tag{5}$$

Then from Equations (1) and (2)

$$T\frac{d^2c}{dt^2} + (K_1+1)\frac{dc}{dt} + c = r \tag{6}$$

This can be converted to the standard second order equation form

$$(T_1^2p^2 + 2\zeta T_1 p + 1)\;c = r. \tag{7}$$

Since the generalized second order equation as normally written requires the right hand side of the equation to be zero, Equation (7) should be converted to one in terms of e rather than c. Therefore:

$$(T_1^2p^2 + 2\zeta T_1 p + 1)\quad (r - e) = r. \tag{8}$$

But if r is a constant then

$$\frac{d^2r}{dt^2} = \frac{dr}{dt} = 0, \text{ and} \tag{9}$$

$$(T_1^2p^2 + 2\zeta T_1 p + 1)\quad (-e) + r = r. \tag{10}$$

Then $$(T_1^2p^2 + 2\zeta T_1 p + 1)\;e = 0, \text{ or} \tag{11}$$

$$[Tp^2 + (K_1+1)\,p + 1]\,e = 0 \tag{12}$$

Now when K_1 is picked in such a manner that $\zeta = 0.35$, the control system of Figure 158 will give its optimum response (i.e., settle out in 1½ cycles of overshoot). See curve A of Figure 159. If K_1 is picked so that $\zeta = 1.0$, curve B on Figure 159, the critically damped case is obtained.

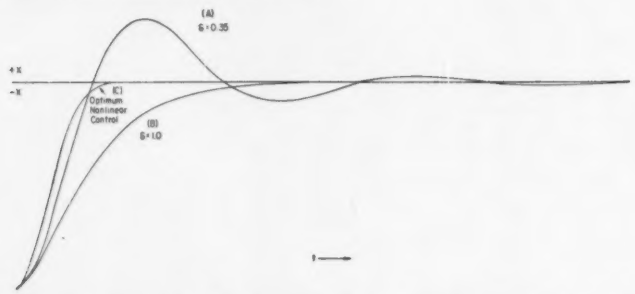

FIGURE 159—It is often possible to obtain a better control response if a nonlinear element is added to a linear control system.

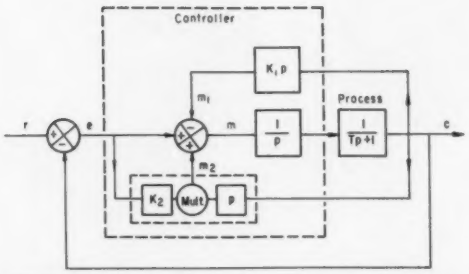

FIGURE 160—Nonlinear damping can be achieved by adding another feedback loop to the system shown in Figure 158.

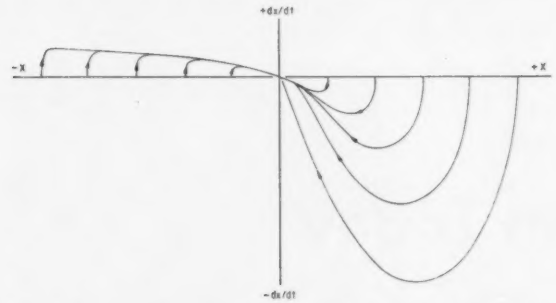

FIGURE 161—The phase plane plot of the system depicted in Figure 160 is not symetrical. This is characteristic of nonlinear systems.

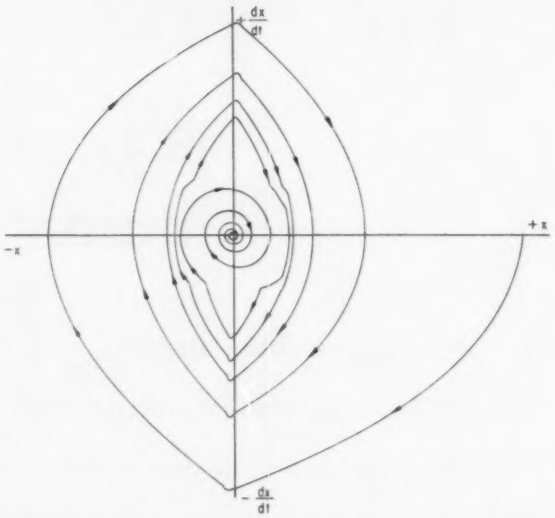

FIGURE 162—For proper settings of K_{max}, a phase plane plot can show maximum restoring force whenever the absolute value of error is greater than a certain amount. Otherwise, the system gives the normally decaying spiral of a linear system.

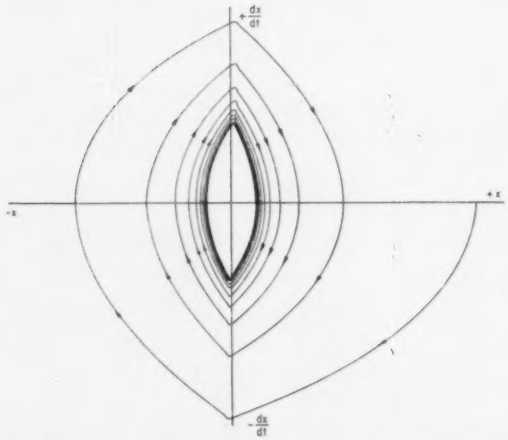

FIGURE 163—If excessive gain is used in the relay control system, the response will approach a limit cycle.

However, as was mentioned in the previous article of this series, it is often possible to obtain a better control response if a nonlinear element is added to a linear control system. Curve C of Figure 159 shows the improved response possible in this way. Note that the system responds faster even than the underdamped system and settles out without any overshoot.

Figure 160 details the additions to the control system necessary for this purpose. It consists of an additional derivative loop, and a proportional side loop from the error detector whose signal is multiplied by the signal from the second derivative element.

The equation for this system is derived as follows using the same symbols and definitions as before:

$$e + m_2 - m_1 = m \tag{13}$$

$$m_2 = K_2 (r - c) \frac{dc}{dt} \tag{14}$$

Then from Equations (1, 3, 5, 13, and 14)

$$T\frac{d^2c}{dt^2} + (K_1 + 1) \frac{dc}{dt} - K_2 (r - c) \frac{dc}{dt} + c = r \tag{15}$$

Now if $(K_1 + 1) = A$,

and $(A - K_2 r) = B$ (16)

then $T \frac{d^2c}{dt^2} + (B + K_2 c) \frac{dc}{dt} + c = r.$ (17)

This quation is nonlinear because of the term $(K^2c)\left(\frac{dc}{dt}\right)$

In terms of e rather than c, the equation becomes

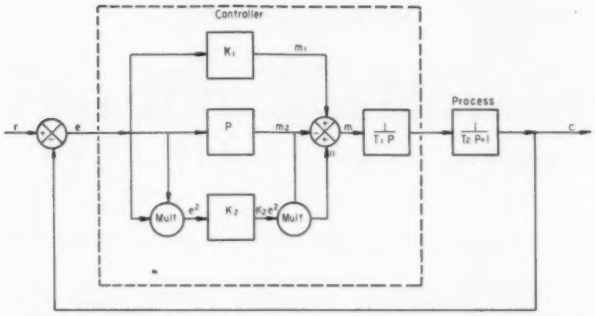

FIGURE 164—There are some nonlinear systems which will always show a limit cycle.

$$\frac{Td^2(r-e)}{dt^2} + [B + K_2(r-e)]\frac{d(r-e)}{dt} + (r-e) = r \quad (18)$$

$$-T\frac{d^2e}{dt^2} - (B + K_2r - K_2e)\frac{de}{dt} - e = 0 \quad (19)$$

$$T\frac{d^2e}{dt^2} + (B + K_2r - K_2e)\frac{de}{dt} + e = 0 \quad (20)$$

Substituting $(A - K_2r) = B$

$$T\frac{d^2e}{dt^2} + (A - K_2e)\frac{de}{dt} + e = 0 \quad (21)$$

The optimum response curve of Figure 159 is for the case where

$K_2 = 0.0921$

$A = 3.33$, and

$T = 1.0$

This particular example is an adaptation of a similar problem appearing in the book "Analysis and Control of Nonlinear Systems," by Y. H. Ku.[3] Many other equally interesting examples are also presented in the literature.[1, 5, 7]

Figure 161 presents the phase plane response of the example system just considered. Compare this response with Figure 155 of Part 22 and note the lack of reproducible symmetry with magnitude changes in the present plot compared to the former one. This as mentioned before is characteristic of nonlinear systems.

LIMIT CYCLES

Since nonlinear systems exhibit the characteristic that their response can change with the magnitude of the signal imposed, some very interesting results can be obtained in phase plane plots of their actions.

Suppose one takes as an example a control system which applies the maximum restoring force whenever the absolute value of the error is greater than a certain amount and which applies normal proportional control whenever it falls below this pre-established level. The control equation will then be:

$$m = +K_{max} \text{ for } e > e_1$$
$$= K_3e \text{ for } -e_1 < e < e_1$$
$$= -K_{max} \text{ for } e < -e_1 \quad (22)$$

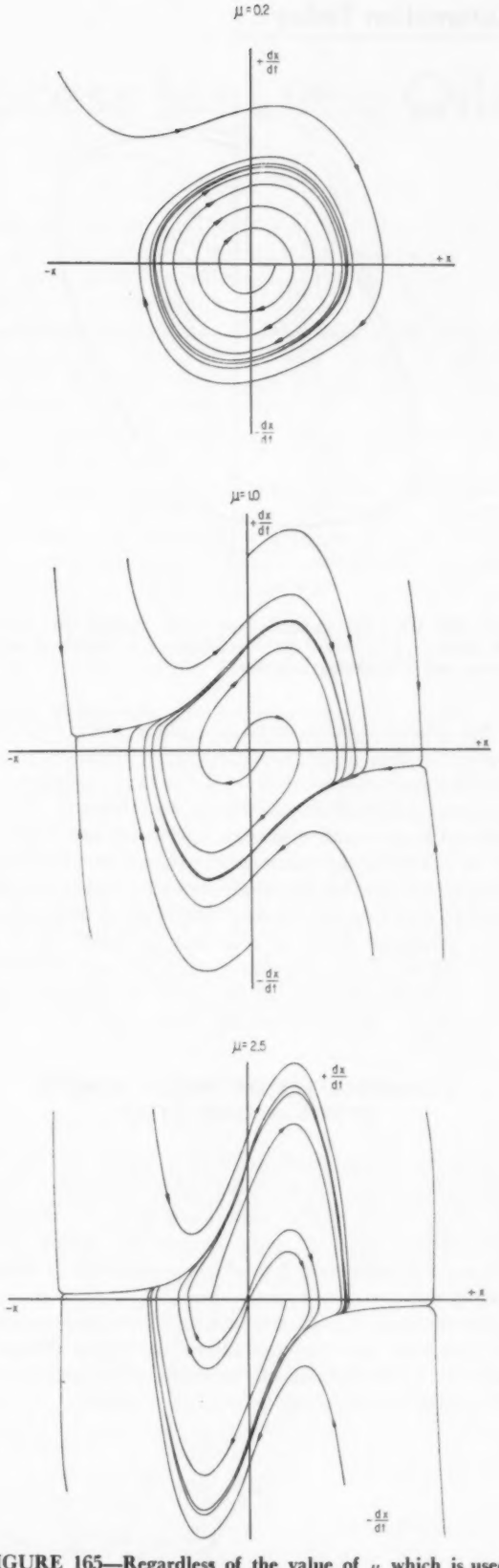

FIGURE 165—Regardless of the value of μ which is used, this system will always exhibit a limit cycle.

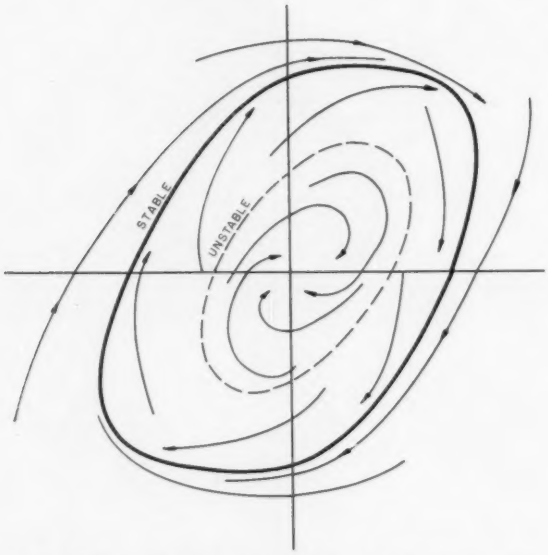

FIGURE 166—The unstable limit cycle (dashed line) shows the boundary between the formation of a sustained oscillation and a decaying response.

For proper settings of K_{max} a phase plane response similar to that of Figure 162 will be obtained. Note that the responses for $-e_1 < e < e_1$ are the normally decaying spirals of the linear system. However, if the value of K_{max} is made too large, a situation may develop where the corrective action is so strong that a sustained oscillation is caused for small errors but not for large ones. In that case the response will decay as before until some minimum value of e is attained after which a sustained oscillation is set up. Such a response is known as a *limit cycle* and occurs frequently in nonlinear systems. Figure 163 illustrates the above case.

A CONTROL SYSTEM WHICH ALWAYS SHOWS A LIMIT CYCLE

There are some nonlinear systems which will always show a limit cycle in their phase plane response no matter what values of the control constants are applied. Such systems must of course be guarded against control system design such as continuous oscillation is highly undesirable.

An example of such a system will now be presented to show how this condition can occur. Figure 164 presents the block diagram of the system to be considered. The system equation can be derived as follows:

$$m_1 = K_1 e \tag{23}$$

$$m_2 = pe = \frac{de}{dt} \tag{24}$$

$$n = K_2 e^2 pe = K_2 e^2 \frac{de}{dt} \tag{25}$$

If $$m = m_1 - m_2 + n \tag{26}$$

then $$m = K_1 e - (1 - K_2 e^2) \frac{de}{dt}. \tag{27}$$

But $$m = T_1 T_2 \frac{d^2c}{dt^2} + T_1 \frac{dc}{dt}. \tag{28}$$

Let $c = r - e$, and equate Equation (27) and (28). (29)

Then $$K_1 e - (1 - K_2 e^2) \frac{de}{dt} = T_1 T_2 \left(\frac{d^2r}{dt^2} - \frac{d^2e}{dt^2}\right) + T_1 \left(\frac{dc}{dt} - \frac{de}{dt}\right) \tag{30}$$

If now $\frac{d^2r}{dt^2} = \frac{dr}{dt} = 0$, because r = constant, (31)

Then $$-T_1 T_2 \frac{d^2e}{dt^2} - T_1 \frac{de}{dt} - K_1 e + (1 - K_2 e^2) \frac{de}{dt} = 0. \tag{32}$$

$$\frac{d^2e}{dt^2} + \left(\frac{1}{T_1 T_2}\right)(T_1 - 1 + K_2 e^2) \frac{de}{dt} + \frac{K_1}{T_1 T_2} e = 0. \tag{33}$$

Let $\frac{K_1}{T_1 T_2} = 1.0$, $\frac{K_2}{T_1 T_2} = \mu$ and $\frac{T_1 - 1}{K_2} = -1.0$ (34)

Then $$\frac{d^2e}{dt^2} + \mu (e^2 - 1) \frac{de}{dt} + e = 0. \tag{35}$$

Note that these equations have been written in terms of e rather than c. This will result only in a sign change which is necessary for our purpose as will be seen below.

Equation (35) is one form of the famous Van der Pol equation[5] which is one of the most famous nonlinear second order differential equations known today. It was originally developed by Van der Pol to explain the nonlinear operation of vacuum tubes but is readily adapted to other systems as we have seen here.

Regardless of the value of μ which is used, this system will always exhibit a limit cycle in its response. Figure 165 shows some typical phase plane responses for various values of μ.

Note particularly an especially important fact about the limit cycles of Figure 165. This is that an error which is less than the limit cycle value is unstable and increases until the limit cycle itself is reached. An error greater than the limit cycle is stable and decreases to the final sustained oscillation value.

Even more complex limit cycle cases can be developed. Figure 166 illustrates one such case. This response can occur with the control surfaces of high speed aircraft. If the excitation is small the control surface oscillation will rapidly damp out to zero. If somewhat larger it may increase to a sustained oscillation. Those values of excitation which define the limit between the formation of a sustained oscillation and a decaying response form what is unown as an *unstable limit cycle*. This is in contrast to the locus of the sustained oscillation itself which is labeled the *stable limit cycle*.

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TO BE CONTINUED

Ferrofining—New Process for Lube Oils

Hydrotreating process has a rugged catalyst that treats straight distillate lubricants which normally receive acid and clay treatment, as well as solvent refined oils

H. F. Dare, British Petroleum Company Limited, London
J. Demeester, Société Francaise des Pétroles, BP, Dunkirk, France

A NEW HYDROTREATING PROCESS for lubricating oils, called Ferrofining, has been developed by the British Petroleum Group. The essential feature of the process is the catalyst which enables not only solvent refined oils to be hydrotreated, but also straight distillate lubricants which normally receive acid and clay treatment. The treated oils have stabilities superior to those obtained when commercially available hydrotreating catalysts are employed.

FIGURE 1—Process was tested in this 8 BPSD pilot plant at BP's Kent refinery.

The process operates at pressures below those of catalytic reformers, and it is thus possible to operate without hydrogen compressors. Average hydrogen consumption amounts to 25 scf/bbl.

The catalyst is rugged and has an expected life in excess of two years.

Estimated investment cost for erection in Northern France of a 3,100-bpsd plant is $495,000, while the operating cost including depreciation is estimated at 19.7 cents per barrel, which is considerably less than the operating cost of conventional finishing treatment processes.

The process has an additional advantage in that the disposal of acid tar and spent clay is eliminated.

Older Processes. The finishing treatment usually employed for lubricating oils is either high temperature contacting with activated clay or percolation through a fixed bed of granular clay. While these treatments yield satisfactory products, both have certain disadvantages in the handling of large quantities of solid matter. Disposal of spent clay is an additional disadvantage in the contact process. Some lubricants require acid treatment in addition to clay treatment and in this case the disposal of acid tar is a further embarrassment. Mild hydrogenation treatment, which has no solids handling problems, is well-known as an alternative to clay,[1] and the existence of catalytic reforming on an extensive scale has made available in most modern refineries a source of cheap hydrogen-rich gas which has stimulated renewed interest in hydrotreating processes.

Research. In the middle of 1954, an investigation into the use of hydrotreating for lubricating oils was started in the British Petroleum Group, both at the Research Centre, Sunbury-on-Thames, England and at the Research Laboratory, S.F.P., BP at Dunkirk, France. After extensive laboratory work on small-scale equipment in which some three hundred catalysts were tested, a catalyst formulation was developed in the S.F.P., BP Laboratory which enabled not only solvent refined oils to be hydrotreated, but also straight distillate lubricants which previously required both acid and clay treatments.[2]

The laboratory work enabled the process conditions to be established on feedstocks from Middle East and South American crudes, but before proceeding to full-scale plant design extensive tests were carried out on a larger pilot plant at BP Refinery, Kent, England, where an 8-bpsd unit was erected in 1958. Figure 1 is a general view of this plant.

Ferrofining—New Process for Lube Oils...

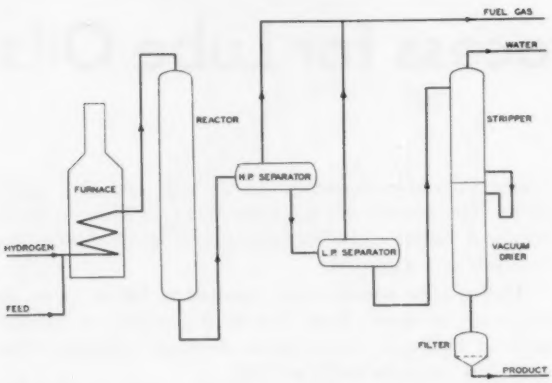

FIGURE 2—Flow scheme for Ferrofining process: By operating at pressures below those of catalytic reformers, no gas compressors are necessary.

Sufficient quantities of products were obtained from the pilot plant to enable a full quality assessment of all grades of lubricants to be made. Additive response was also determined.

Following the successful outcome of the pilot plant work, a full process design has been completed for a 3,100-bpsd Ferrofining unit to be installed at the Dunkirk Refinery of S.F.P., BP, and further units within the BP Group are under consideration.

Process Description. Ferrofining consists essentially of passing the lubricating oil and hydrogen through a fixed bed of catalyst under moderate conditions of temperature and pressure. The essential feature of Ferrofining is the catalyst, since by its use the process is capable of treating to a desirable degree of stability not only solvent refined lubricants, but also straight distillate lubricants which normally receive acid and clay treatment to produce the necessary degree of thermal stability.

Ferrofining has been developed in such a manner that it can be operated at pressures below those of catalytic reformers, and it is thus possible to operate the plant without gas compressors. The process consumes only a small amount of hydrogen and under normal circumstances hydrogen recycle is unnecessary. Average consumption is 25 scf/bbl.

The research carried out on different feedstocks has shown that the operating conditions for optimum quality vary according to the viscosity of the oil, the degree of refining and origin of crude oil. The operating temperature and space velocity are also functions of feedstock type. The Ferrofining operation is carried out at such temperatures, however, that very little desulphurisation occurs, and the production of H_2S is very low. As a result, the plant is simple and cheap and the reactor section can be constructed of inexpensive carbon—½ percent molybdenum steel.

Figure 2 is a flow diagram of a Ferrofining unit. The mixture of oil and gas rich in hydrogen passes through the heater where it is raised to the treatment temperature and then flows in a downward direction through the bed of catalyst in the reactor. The oil and gas leaving the reactor are separated in two stages. The gas from both stages passes to refinery fuel mains, while the oil from the second stage is stripped with steam and dried in a vacuum column to obtain a product with the required flash point. The finished oil is finally pumped to stock via a cartridge filter or similar apparatus.

The catalyst employed is a rugged three-component catalyst on an alumina base of good physical characteristics, ensuring long mechanical life. A charge has been in continuous operation in a pilot plant for 13 months, treating various oils, without any sign of reduction in activity. It appears, therefore, that regeneration, if necessary at all, would only be required at infrequent intervals. During the development of the catalyst it has been demonstrated that full activity can be restored by a simple burn-off with steam/air mixtures.

Quality of Ferrofined Oils. Exhaustive tests have been carried out on various grades of lubricating oils. In the early part of the investigation it was found that catalysts which were then available commercially were insufficiently active to provide oils having the desired degree of stability. Other characteristics, such as color and carbon residue, were easily obtained by the conventional catalysts.

The Ferrofining process produces lubricants with an excellent resistance to oxidation, as shown in Tables 1-3. Table 1 compares the oxidation stability of solvent refined Middle East lubricants finished by three processes, conventional clay, hydrogenation with commercial cobolt molybdate catalyst, and Ferrofining. The degree of stability obtained in these cases was measured by the British Air Ministry Oxidation Test, IP 48/57. In Tables two and three are shown respectively, comparative data on straight dewaxed Middle East distillate lubricants, and distillates from Tia Juana 102 crude. In these cases the color stabilities were measured by determining the color before and after heating the oil for 16 hours at 185° F in the presence of air. It will be

TABLE 1—Comparative Stability[1] of Solvent Refined Middle East Lubricants

Treatment	Clay Contacted	Hydrotreated with CoMo Catalyst	Ferrofined
500 Pale 75 V.I.			
Clay treatment, Percent Weight	4	.....	.....
Color, ASTM	3 minus	2½ minus	2½ minus
Viscosity ratio	1.7	1.8	1.6
Carbon residue increase	1.5	1.8	1.4
500 Neutral 95 V.I.			
Clay treatment, Percent Weight	2	.....	.....
Color, ASTM	3 minus	1½ minus	2 minus
Viscosity ratio	1.2	1.3	1.2
Carbon residue increase	0.3	0.6	0.3
Bright Stock 170 SSU at 210 °F, 85 V.I.			
Clay treatment, Percent Weight	3	.....	.....
Color, ASTM	6 minus	4	4
Viscosity ratio	1.7	1.9	1.6
Carbon residue increase	1.5	1.8	1.2
Bright Stock 160 SSU at 210 °F, 95 V.I.			
Clay treatment, Percent Weight	2	.....	.....
Color, ASTM	3½	2	2
Viscosity ratio	1.3	1.3	1.2
Carbon residue increase	0.7	0.7	0.5

[1] The oxidation stabilities are measured by the British Air Ministry Oxidation Test (IP Method 48/57).

TABLE 2—Comparative Color Stability[1] of Middle East Straight Distillate Lubricants

Treatment		Acid & Clay	Hydrotreated with CoMo Catalyst	Ferrofined
Distillate 100 SSU at 100 °F, 50 V.I.				
Acid treatment	Percent Weight	1.2	.....	.....
Clay treatment	Percent Weight	5.5	.....	.....
Color	ASTM	2 minus	1½ minus	1½ minus
Color after aging	ASTM	2	2 minus	1½ minus
Distillate 55 SSU at 210 °F, 55 V.I.				
Acid treatment	Percent Weight	5	.....	.....
Clay treatment	Percent Weight	8	.....	.....
Color	ASTM	2½ minus	2 minus	2 minus
Color after aging	ASTM	3 minus	3 minus	2½ minus
Distillate 85 SSU at 210 °F, 50 V.I.				
Acid treatment	Percent Weight	4	.....	.....
Clay treatment	Percent Weight	4	.....	.....
Color	ASTM	3½ minus	3 minus	3 minus
Color after aging	ASTM	5 minus	4½	3½

[1] Stability is measured by the increase in color after aging for 16 hours at 185 °F.

TABLE 3—Comparative Stability[1] of Tia Juana Distillate Lubricants

Treatment		Acid & Clay	Hydrotreated with CoMo Catalyst	Ferrofined
Distillate 115 SSU at 100 °F, 24 V.I.				
Acid treatment	Percent Weight	2	.....	.....
Clay treatment	Percent Weight	4	.....	.....
Color	ASTM	1½	1½ minus	1½ minus
Color after aging		2 minus	2 minus	1½ minus
Distillate 55 SSU at 210 °F, 40 V.I.				
Acid treatment	Percent Weight	5	.....	.....
Clay treatment	Percent Weight	6	.....	.....
Color	ASTM	2 minus	1½ minus	1½ minus
Color after aging		2½	2½ minus	1½

[1] Stability is measured by the increase in color after aging for 16 hours at 185 °F.

TABLE 4—Estimated Investment Cost of a 3,100 BPSD Ferrofining Unit

	Erected Northern* France Basis $
Process, materials	$169,000
erection	55,000
Civil engineering works (site foundations, buildings etc.)	90,000
Insurance and consumable materials of erection	7,000
Design and engineering	90,000
Process unit erected cost in battery limits	411,000
Initial catalyst charge	64,000
Plant spares (direct cost)	20,000
Estimated total investment cost	$495,000

* Before local capital taxation.

TABLE 5—Estimated Operating Cost of a 3,100 BPSD Ferrofining Unit
Basis: 330 operating days

	Northern France Basis $/SD
Depreciation @ 10% of process unit erected cost	125
Labor and supervision	
2 operators/shift (4 shift basis) @ $1.40/hr.	74
Supervision	25
Catalyst	
Ferrofining catalyst assumed life 2 years	97
Hydrogen	
25 scf/bbl = 77.5 Mscf/day @ FOE	11
Maintenance	
Materials and labor @ 3% of process unit erected cost	37
Utilities	
Fuel: 6.7 x 10^6 Btu/hr liberated (=365 lb/hr) = 25.65 bbls @ $3.00/bbl	77
Steam: 5.4 x 10^3 lb/hr @ $1.10/1,000 lbs.	143
Cooling water: (18 °F temperature difference): 11.6 x 10^3 USG/hr = 1.3¢/1,000 gals.	3
Power: 2,100 KW @ 0.95¢/kwh	20
Estimated total operating cost (before interest, taxes, royalty and overheads)	$612
= per bbl	19.7 cents

seen that in all cases Ferrofined oils are better than those produced by the conventional processes.

Ferrofined oils have been formulated with additives into motor and diesel engine oils, and have been subjected to a comprehensive series of engine tests and also to special tests designed to measure engine wear. All these tests showed the oils to have exactly the same performance as those treated by conventional clay. Their suitability for speciality products has also been confirmed.

Economics of the Process. The estimated investment costs of a 3-100-bpsd Ferrofining unit erected in Northern France are given in Table 4. These are bare costs within battery limits and have been converted at $1.00 = 4.9 NF. Offsite facilities such as power and steam generation, tankage and transfer facilities, cooling water, etc., have not been included because these were readily available on the site. However, utilities costs have been priced into the estimated operating costs at levels which pay for associated offsite installations over the long term.

The estimated operating costs are given in Table 5 in such a manner that they can be adjusted for individual locations. The total operating cost compares most favorably with conventional treatment costs and is, in fact, little more than the cost of the activated clay normally used in the clay treating process. A further advantage, which is common to most hydrotreating processes, is that the yield of refined product exceeds 99 percent.

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About the Authors

Dare

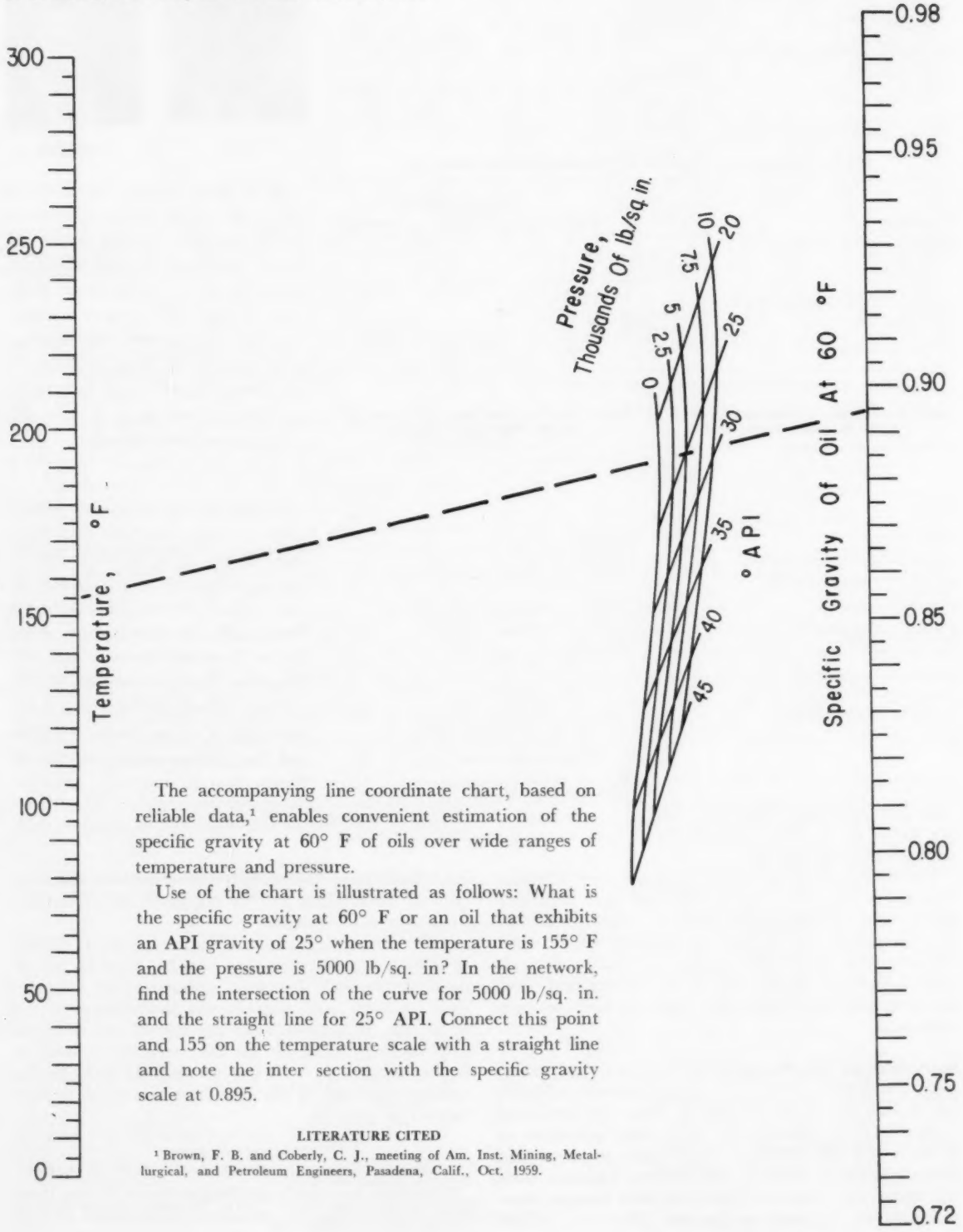
Demeester

H. F. Dare manages the lubricants and lubricating oil processes branch in the Technical Development Division, British Petroleum Company. He received his B. Sc. (Hons.) from Wales. After serving at BP's refinery in Llandarcy from 1923 to 1936, Mr. Dare was transferred to the Research Center at Sunbury-on-Thames. Since then, he has specialized in the study of lube oils, waxes, greases and bitumens.

J. Demeester, graduate in physical sciences of the Universite Catholique, Lille, France, is in charge of the research laboratories at the Dunkirk refinery of the Societe Francaise des Petroles BP, French subsidiary of the British Petroleum Company Ltd. Mr. Demeester joined the company in 1953 and had worked previously as a chemical engineer on the Fischer Tropsche and Oxo syntheses with Kuhlmann at Harnes, France.

How Pressure Affects Gravity of Oils

D. S. Davis, University of Alabama, University, Ala.



The accompanying line coordinate chart, based on reliable data,[1] enables convenient estimation of the specific gravity at 60° F of oils over wide ranges of temperature and pressure.

Use of the chart is illustrated as follows: What is the specific gravity at 60° F or an oil that exhibits an API gravity of 25° when the temperature is 155° F and the pressure is 5000 lb/sq. in? In the network, find the intersection of the curve for 5000 lb/sq. in. and the straight line for 25° API. Connect this point and 155 on the temperature scale with a straight line and note the inter section with the specific gravity scale at 0.895.

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New Tests on Carburetor Icing

Simple engine tests just developed show icing characteristics of gasoline. Additive requirements can be predicted from these tests or from physical properties of the gasoline

H. J. Scheule and J. G. Burt
E. I. duPont de Nemours & Company, Inc.
Wilmington, Del.

CARBURETOR ICING tendencies of commercial gasoline can be predicted with two engine tests just developed. These tests can be used to determine anti-icing additive requirements. This study also shows that physical properties of the gasoline can be used to determine additive needs. To prevent annoying engine stalls, refiners frequently incorporate antistall additives in their gasolines. The concentrations of these materials required for satisfactory performance are sometimes difficult to determine because of the many engine and fuel variables that must be considered.

Techniques for measuring the carburetor icing characteristics of gasolines are relatively new though the icing problem is an old one.[1,2] There are at present no generally accepted standards for measuring this quality of gasoline, but the increased activity in this field has resulted in the development of several test methods. While these methods differ considerably in detail, they are of two basic types: (1) those with changing operating conditions in which icing performance is measured in terms of the number of stalls prior to engine warmup, and (2) those with constant operating conditions in which the icing tendencies are measured in terms of the operating time required to cause stalling as the result of ice formation. Although methods falling in the second category may not be as realistic as methods in which the engine warms up in a normal way, they do have the advantages of short testing times and reasonably good reproducibility. Two tests of this type, devloped in the DuPont Petroleum Laboratory, have proved useful in evaluating anti-icing additives and determining the icing tendencies of commercial gasolines.

TABLE 1—Calculation of the "Effective Evaporation" of a Gasoline from its ASTM Distillation

Fraction in ASTM Distillation, %	Boiling Range, °F	Average Boiling Point, °F	Effective Evaporation of Fraction, % (Figure 3)	Contribution to Effective Evaporation, %
IBP-5	97-112	103	100	5.0
5-10	112-118	115	98	4.9
10-20	118-124	121	96	9.6
20-30	124-132	128	94	9.4
30-40	132-142	137	90	9.0
40-50	142-154	148	85	8.5
50-60	154-167	161	78	7.8
60-70	167-184	181	66	6.6
70-80	184-206	195	56	5.6
80-90	206-240	223	35	3.5
90-95	240-282	261	15	.8
95-EP	282-322	302	5	.3
Total Effective Evaporation.....				71.0

Single-Cylinder Engine Test Method. The first of these methods employs a single-cylinder engine with a CFR ice tower and an ice-jacketed carburetor, as shown in Figure 2. The ice tower provides nearly saturated air (95 percent relative humidity) at approximately 40°F. The ice jacket on the carburetor maintains constant-temperature conditions in this area and minimizes the effects of heat radiation from the engine. Also, because of the low fuel-to-metal ratio associated with most single-cylinder-engine carburetors, a jacket of this type is necessary to maintain the temperature of metal parts within the range where carburetor icing occurs. The engine is a Model H-2 Lauson connected to a synchronous motor dynamometer.

The testing procedure involves operating the engine at 1,750 rpm with two-thirds throttle opening for a specified period of time. The throttle plate is then returned to the idle position, the engine is disengaged from the dynamometer, and its idle performance is observed. Numerical ratings ranging from 1 to 5 are then assigned to the fuel. A rating of 1 represents no loss in idle speed, a rating of 5 represents a rapid and complete stall, and intermediate ratings represent varying degrees of slow idle or partial stall.

This procedure was developed and employed primarily for comparing the performance of anti-icing

additives. As experience was acquired with commercial gasoline, however, a standard test time was established which provides reasonable assurance against carburetor icing under field conditions. Concentrations of a freeze-point depressant additive which gave a significant reduction in stalling in the laboratory test were found to effect satisfactory reductions in the frequency of carburetor icing complaints in commercial applications.

Gasoline Volatility and Carburetor Icing. In addition to serving as a tool for evaluating anti-icing additives and predicting additive requirements, this single-cylinder engine test has proved useful in demonstrating the importance of gasoline volatility.

It is generally agreed that the change in temperature of the air/fuel mixture in the throttle body, and hence the icing tendency of a gasoline, is related to the amount of fuel evaporated in the carburetor. Therefore, the fraction of the fuel evaporating at or before the throttle plate may be calculated from the measured temperature drop and the heat of vaporization of the fuel, assuming adiabatic conditions and condensation of water to the dew point of the cooled air. The relationship shown in Figure 3 was developed in this manner for pure hydrocarbons, expressing percent evaporation as a function of hydrocarbon boiling point.

The temperature drop recorded when the engine is operated on n-pentane indicates that 100 percent of this fuel is evaporated in the throttle body of the carburetor under the conditions of the test. In comparison, the temperature drop with ethyl cyclohexane indicates evaporation of only 13 percent of the fuel. Toluene, with a boiling point of approximately 230°F, provides an air/fuel mixture temperature of 32°F and, therefore, represents the minimum volatility at which carburetor

Why Carburetors Ice and How to Reduce it

Ice forms on the throttle plate of a carburetor during the first few minutes of engine operation in cool, humid weather. The evaporating fuel in the carburetor cools the humid air passing into the engine, forming ice crystals on the throttle plate. Eventually enough ice is formed to block the narrow passage around the nearly closed throttle plate when the engine is idled (Figure 1) and the engine stalls. Icing most often occurs at atmospheric temperatures of 32° to 55° F and relative humidities above 50 percent. It is most severe when temperatures are about 40° F and the relative humidity is above 90 percent. These conditions are quite common during the fall and spring months in most areas with a temperate climate.

The frequency of stalls from carburetor icing can be reduced in several ways: by mechanical changes, by fuel volatility, and by additives. Mechanical changes, such as increasing carburetor heat or heating the incoming air, are only partially successful or expensive. Fuel volatility can be reduced, but such changes are limited by the availability of blending stocks and by the need for sufficient volatility for quick starting and rapid warm-up. A common solution is through the use of gasoline additives.

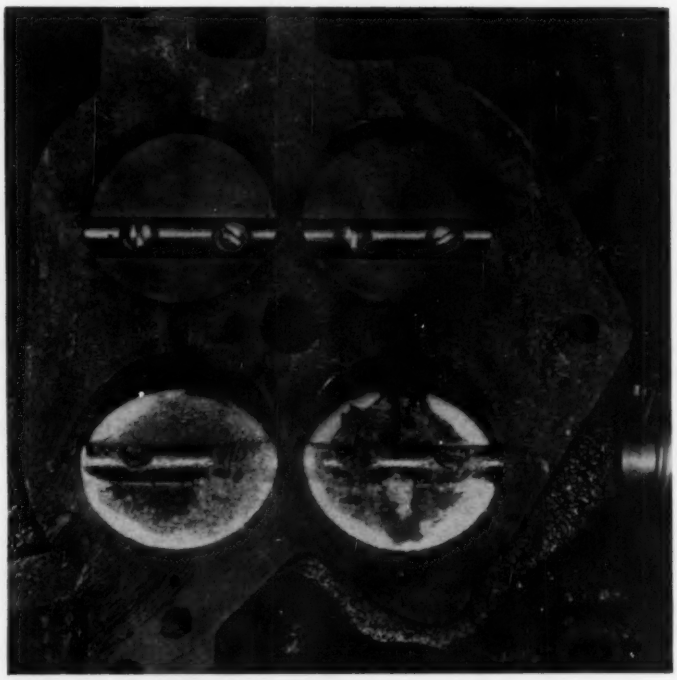

FIGURE 1—Ice forms in low-speed barrels of a four-barrel carburetor.

The additives commonly used are of two types. The first commercially used anti-icing additives prevented the freezing of condensed water by depressing its freezing point. Because of the way they work, fairly high concentrations of freeze-point depressant additives are required. They are easily extracted by water and some can promote rusting of steel. Additives of a surface-active or surfactant type are now more widely used. These are effective at much lower concentrations and, frequently, also have some activity as antirust agents and carburetor detergents.

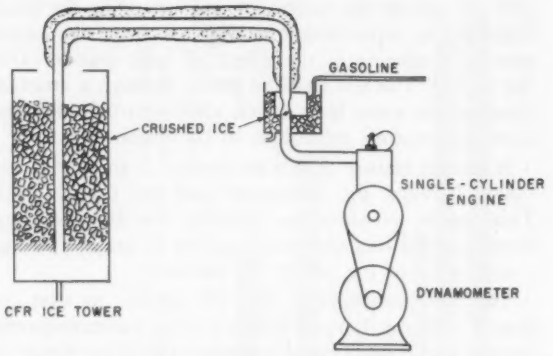

FIGURE 2—Equipment used in single-cylinder engine icing tests.

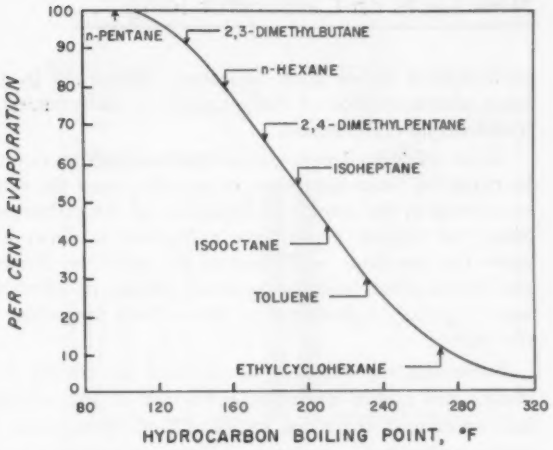

FIGURE 3—Relation between fuel boiling point and evaporation in single-cylinder icing tests.

icing can occur under the conditions of this test. It can be calculated that 23 percent of the toluene evaporated.

To apply the information developed in Figure 3 when comparing the volatility properties of commercial gasolines, it is necessary to make two additional assumptions: (1) that the heats of vaporization of hydrocarbons in the gasoline boiling range are essentially equivalent, and (2) that a gasoline behaves as a series of pure hydrocarbons with the average boiling points of the gasoline fractions.

In Table 1, a gasoline has been treated as a mixture of pure hydrocarbons with boiling points which are the average distillation temperatures for each ASTM distillation fraction, as shown in the second column. The evaporation that would be anticipated for each fraction, based on the curve shown in Figure 3, is shown in the third column. The fourth column is the value of the percent evaporation corrected for the percentage each fraction represents of the entire fuel. An estimate of the percent of the gasoline that will be evaporated is obtained by adding the contributions of the various fractions. This figure is designated "effective evaporation" in the discussion to follow. Precision of the calculated effective evaporation can be increased by employing more fractions of narrower boiling ranges, especially in the more volatile portions of the fuel.

The significance of this effective evaporation number can be shown by plotting it against carburetor icing tendency for a series of commercial gasolines and pure hydrocarbon blends, as shown in Figure 4. In this relationship, the icing tendencies of the fuels are conveniently expressed in terms of an additive requirement for stall-free operation. This technique for comparing fuels has been used frequently with the single-cylinder engine test in preference to changing the test severity.

It may be noted that a straight-line relationship is obtained when the freeze-point-depressant additive requirement is plotted on a logarithmic scale. It is necessary in such plots to restrict the data to those obtained with pure hydrocarbons and paraffinic gasolines. Data obtained using commercial fuels having high aromatic and olefinic contents fall below the curve for paraffinic hydrocarbons. Other tests have shown that this effect is due to the influence of hydrocarbon type on additive

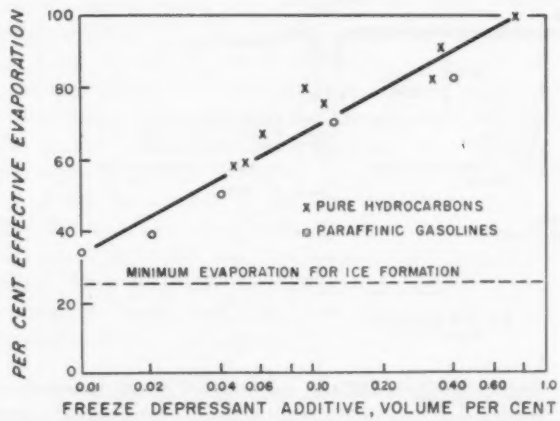
PER CENT EFFECTIVE EVAPORATION
x PURE HYDROCARBONS
o PARAFFINIC GASOLINES
MINIMUM EVAPORATION FOR ICE FORMATION
FREEZE DEPRESSANT ADDITIVE, VOLUME PER CENT

FIGURE 4—Effective evaporation is closely related to anti-icing additive requirement for pure hydrocarbons and paraffinic gasolines.

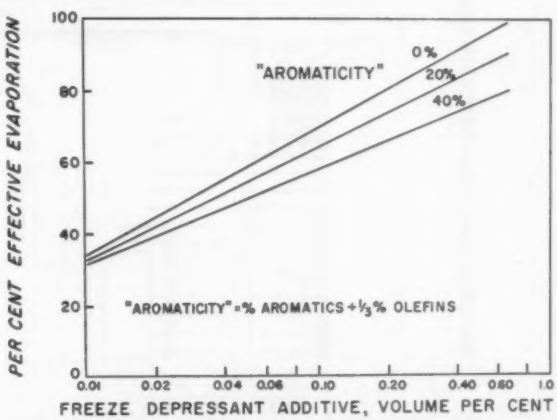

FIGURE 5—Relation between effective evaporation and additive requirement changes for different aromaticity in gasolines.

performance rather than to actual differences in the icing characteristics of fuels caused by differences in hydrocarbon composition.

To be effective, freeze-point-depressant additives must be extracted from the hydrocarbon phase into the water condensed in the throttle body section of the carburetor. Since the degree of additive extraction is dependent upon the partition coefficient of the additive between the hydrocarbon and the aqueous phases, its effectiveness is greatly influenced by the solvent properties of the fuel.

Increasing the solvency of the fuel by adding aromatics and olefins decreases extraction of the additive into water and, therefore, increases the concentration of additive required to maintain a given performance level.

Figure 5 presents a family of curves relating effective evaporation and freeze-point-depressant additive requirement at various "aromaticity" levels. "Aromaticity" as defined in this relationship is the percent aromatics plus one-third the percent olefins in a fuel. In our studies, this relationship has provided a useful indication of the influence of these fuel components on freeze-point-depressant additive requirements.

Multicylinder Engine Test Procedure. While useful in evaluating carburetor icing additives and in theoretical evaluations, the single-cylinder engine test was not completely satisfactory because of the design of the carburetor used and the occasional erratic operation common with single-cylinder engines. A second procedure was, therefore, developed which employed a six-cylinder engine and the other equipment illustrated in Figure 6.

In this procedure, humidified air is forced through an ice tower and then through an insulated and ice-water cooled air duct into and around the carburetor. Passing cold air around the carburetor and extending the intake manifold to separate the carburetor from the engine essentially eliminates the effect of heat transfer from the engine. The test gasoline passes through a constant-temperature water bath which also helps maintain constant-temperature conditions in the carburetor.

A unique feature of this equipment is an acrylic resin spacer between the carburetor and the throttle body. This spacer provides for lighting the throttle plate, thereby permitting observation of ice formation through a sight glass at the top of the air duct.

The test procedure is basically similar to that employed with the Lauson engine except for more precise control and consequently improved precision. Once the engine has been cooled to equilibrium conditions by operating on humidified air from the ice tower, a test run is conducted as follows.

First, ten milliliters of methyl alcohol are introduced onto the closed throttle plate through a tube extending through the carburetor jacket. After 10 seconds to allow for dissolving from the throttle plate any surfactant additives or other materials which could affect the subsequent test, the throttle plate is opened and the engine started. As soon as the alcohol is cleared from the system (3 to 5 seconds), the throttle plate is returned to the idle position and the engine operated at idle on room air until the throttle plate temperature stabilizes at 34°F.

The test run is started at this point by opening the throttle to a setting which provides 1,500 rpm at a 10 hp loading and switching the air supply from room air to cool, humidified air (approximately 40°F and 99 to 100 percent relative humidity) from the ice tower. Ice formation is observed through the sight glass in order to estimate the operating time required for formation of enough ice to cause stalling when the throttle plate is returned to the idle position. After sufficient ice has formed, the throttle plate is returned to the idle position.

If the engine stalls, the test procedure is repeated as

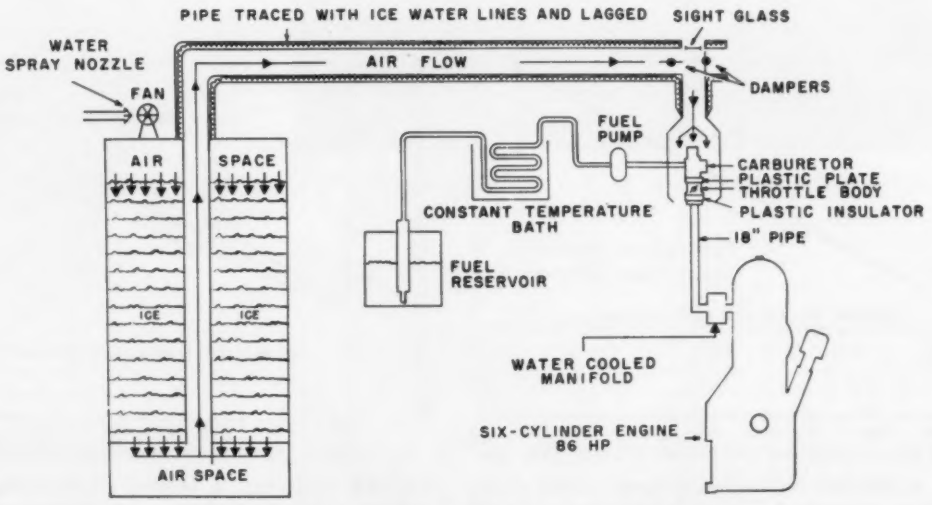

FIGURE 6—Equipment used in multicylinder engine icing tests.

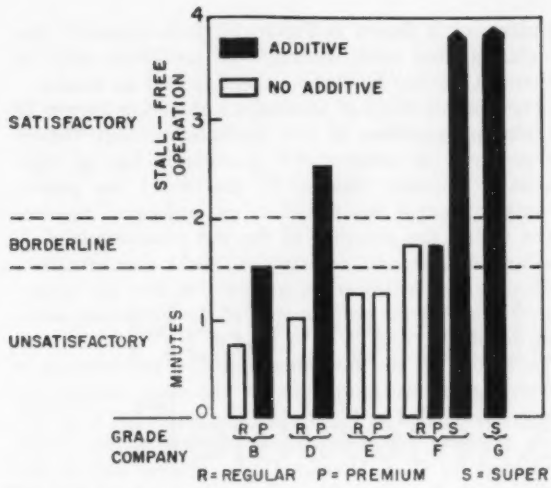

FIGURE 7—Carburetor icing properties of East Coast gasolines (Spring 1958).

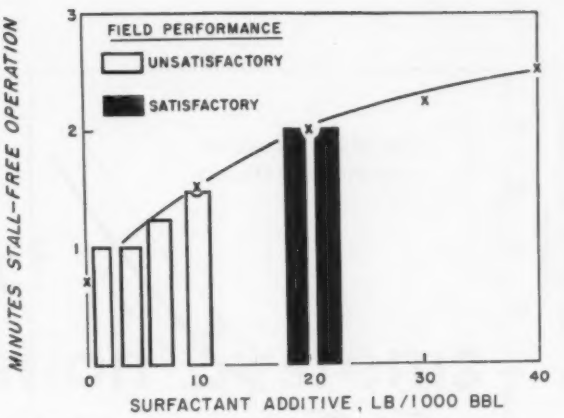

FIGURE 8—Field tests supported laboratory data (shown by curve) for satisfactory operation.

outlined, using a shorter operating interval until no stalling occurs when the throttle is returned to the idle setting. The time required for stalling is bracketed in this manner and eventually established within a 15-second interval. The time, thus determined, represents the rating of the specific fuel or fuel-additive combination under test.

This procedure is rapid and reproducible. The correlation between the results obtained and customer experience was determined by tests with a number of commercial gasolines of known carburetor icing performance. Ratings obtained are shown in Figure 7. Based on these results, limits for satisfactory, borderline, and unsatisfactory performance were established. These limited data were subsequently supported by field tests like the one summarized in Figure 8.

Figure 8 relates engine operating time for stall-free performance to the concentration of a surfactant additive in a large scale field trial. The curve in this figure represents the original laboratory data obtained on this fuel. An additive concentration of 20 pounds per 1,000 barrels was employed. In the early fall, during the initial period of the trial, a concentration of 10 pounds per 1,000 barrels was used and some complaints of carburetor icing were received. Samples were obtained at that time and evaluated in the laboratory test engine. The results obtained on these samples, all of which contained 10 pounds or less of the additive per 1,000 barrels, are represented by the open bars in the figure. After the additive concentration had been increased to 20 pounds per 1,000 barrels, samples were again obtained. They gave stall ratings of two minutes. Field complaints ceased and none were received for the remainder of the carburetor icing season.

Carburetor Icing Properties of Commercial Gasolines. Another application for which the carburetor icing test has been found useful is illustrated in Figure 9. This figure summarizes the results obtained in a survey of the carburetor icing characteristics of commercial gasolines. This survey, which was conducted during March 1959, consisted of the evaluation of 20 regular-grade, 20 premium, and 4 super-premium gasolines.

Results of this survey are expressed in two ways. In Figure 9 the bars in the foreground represent the percentage of gasolines by grade which were rated satisfactory with respect to carburetor icing characteristics by the laboratory test. The background bars represent the percentage of fuels, again by grade, which reportedly contained an anti-icing additive. In both the regular and premium gasolines, a slightly higher percentage of fuels contained additives than were found to be satisfactory by the test, indicating that some of the additives were ineffective or were not present in sufficient quantities to provide protection.

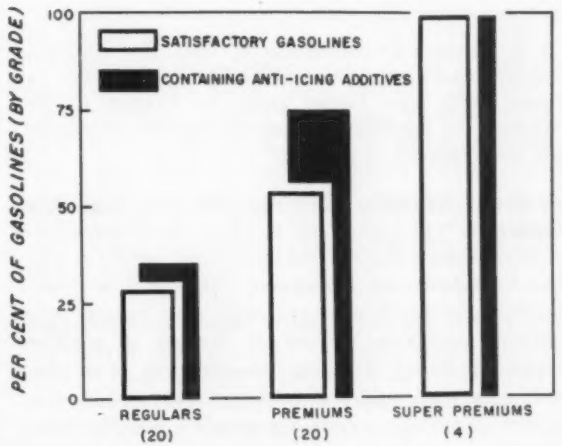

FIGURE 9—Carburetor icing properties of commercial gasolines in March 1959. Some additives were not effective or not in high enough concentration.

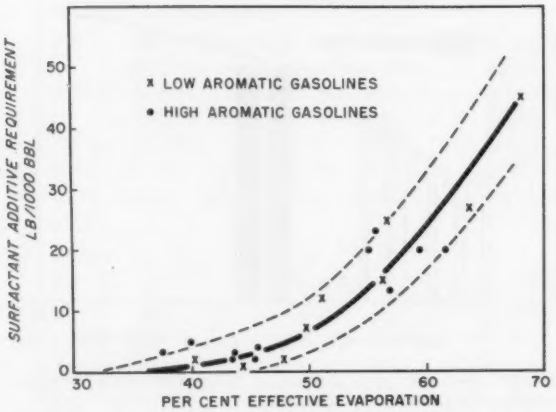

FIGURE 10—Relation between surfactant antistall additive requirement and effective evaporation also shows the effect of aromaticity.

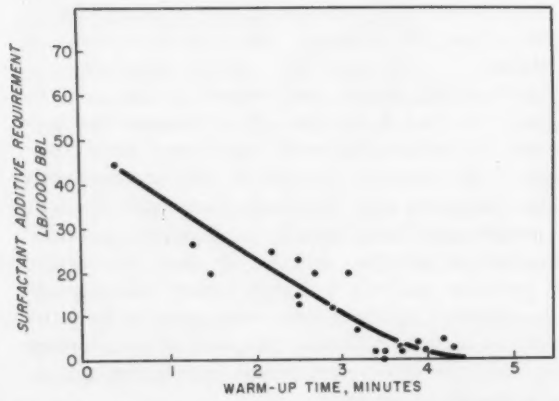

FIGURE 11—Warm-up times are related to antistall additive requirement.

It is particularly interesting to note the emphasis presently placed on carburetor icing characteristics by refiners. With each higher grade an increase in the percentage of gasolines protected against carburetor icing was observed.

Surfactant Additive Requirements and Gasoline Properties. The engine test has been used extensively for determining surfactant additive requirements of gasolines for commercial application. Although these determinations are rapid and reliable, the results were sometimes uncertain because of changes in gasoline composition during handling. Development of a relationship between additive requirement and readily available physical data on the gasoline was therefore desirable.

The correlation between "effective evaporation", calculated as previously described, and surfactant additive requirement is shown in Figure 10. It is apparent that a relation does exist, although its usefulness may be somewhat limited by the indicated spread in results.

The possible effect of aromatics is shown in Figure 10 by plotting gasolines of low aromatic content (below 20 percent) as crosses and gasolines having high aromatic content (above 20 percent) as points. Aromatic content has no effect on surfactant requirement within the accuracy of the test measurements. A similar study showed no effect of olefin concentration, indicating that hydrocarbon composition does not appreciably influence the performance of the surfactant additive involved.

In Figure 11 the surfactant additive requirement is plotted against warm-up time for the same commercial gasolines included in Figure 10. The warm-up times for these gasolines were determined using the rating system developed by C. J. Domke, C. B. Tracey, and H. R. Taliaferro.[3] A reasonable relationship was obtained, indicating that gasolines having good warm-up performance will probably exhibit some carburetor icing problems unless they contain anti-stall additives. It is highly unlikely that a gasoline having both excellent warm-up and excellent icing characteristics can be blended without the assistance of an effective anti-icing additive. The ability to measure and control the carburetor icing characteristics should prove useful in the blending of gasolines so as to take advantage of maximum volatility and at the same time provide adequate protection against carburetor icing.

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[2] W. P. Dugan and H. A. Toulmin; "Carburetor Icing Tendencies of Some Present Day Fuels and Engines"; SAE Transactions, 63, 442 (1953).
[3] "Effect of Gasoline Volatility on the Performance of Passenger Cars," Proc. API, III 33, 112, 1953.

About the Authors

Harold J. Scheule is supervisor of the gasoline and TEL group at the DuPont Petroleum Laboratory in Wilmington. After receiving his B.S. degree in chemical engineering from Bucknell University in 1943, Mr. Scheule worked for the Phillips Petroleum Company in process design and development for three years. Since then, his activities have been in the field of petroleum additives with the Petroleum Chemicals division of DuPont.

Scheule

Burt

Dr. James G. Burt is a research chemist in the DuPont Petroleum Laboratory. He received his B.A. degree from Oberlin College, his M.S. and Ph.D. from the University of Chicago. Dr. Burt has spent the past eleven years in research in various DuPont laboratories, the last five being spent in petroleum additive work.

How to Select Demineralization Systems

From these data you can select basic resins and system types. You also can determine capital investment and operating costs for ion exchange water treatment systems

N. H. Prater and D. W. Antonacci
The Chemstrand Corporation
Pensacola, Fla.

THE CHOICE of method and type of ion exchange resin for a demineralization process depend on many factors, including the composition of the raw water, the degree of treatment required, and the purpose for which the treated water is to be used. Simple guides and explanations of the many systems available and the multitude of combinations possible are often confusing since they, of necessity, sacrifice complete coverage of some points that are of importance to a particular reader. Therefore, the following discussion is intended to convey only a general scope of demineralization as applied to industrial water treating.

The major dissolved impurities in natural water are iron, calcium, sodium, magnesium, manganese and potasium cations in various combinations with the carbonate, bicarbonate, sulfate, chloride, nitrate, and silicate anions. Here calcium and magnesium constitute the "hardness" of a water while carbonates and bicarbonates are called "alkalinity." The appropriate demineralization process will remove these cations and anions from water by exchanging all salts of the cations to their acids in a hydrogen cation exchanger, then removing these acids with an anion exchanger.

The demineralization plant can be put together from a number of simple ion exchange units. The particular type of exchange resin required depends on the degree of water treatment desired. Normally the first step involves a strongly acidic cation exchange resin operated in the hydrogen form. When raw water is passed through this unit, the soluble salts present are converted to their corresponding acids. The acidic effluent water can then be passed through a second unit filled with an anion exchange resin. If a weak base anion resin is employed, only mineral acids will be removed and the weakly ionized materials, i. e. silica, carbon dioxide, etc. will remain in solution. This arrangement is shown in Figure 1. If the carbon dioxide cannot be tolerated, it can be effectively reduced to 5-10 parts per million by a degassifier installed ahead of the weak base unit. This arrangement is illustrated in Figure 4. The weak base anion is very efficient for removing strong acids and, therefore, is very useful when the raw water is high in sulfates and chlorides. It can be regenerated at 70 to 85 percent efficiency with soda ash, ammonium hydroxide or caustic soda.

Strong base anion resins exhibit a high efficiency for removing weakly acidic impurities such as carbon dioxide, hydrogen sulfide, silica, etc. They will remove both strong and weak acids and is usually regenerated with caustic soda. If regenerated with sodium chloride, all constitutents in the water will be converted to chlorides. Conversely, when caustic soda is used, all salts such as sodium sulfate or chlorides will be split over to caustic soda.

Regeneration Rate. When the cation unit is regenerated with acid, the resin exchanges hydrogen ions for metallic ions forming acids of the salts present in the raw water. Conversely, when regenerated with a salt such as sodium chloride, it exchanges sodium ions for other metallic cations forming sodium salts. Sulfuric acid is usually used for the cation regeneration at a rate of about 2-4 ppm for each part-per-million cation pro-

duced. Similarly, caustic soda is used in quantities equal to 1-2 ppm of acid removed in the weak base exchanger and 2-3 ppm for the same equivalent amount of acid removed in a strong base exchanger. These quantities can vary widely and the resin manufacturer should be consulted for specific applications.

Equivalent Factors. Calcium carbonate is used as the basis upon which water analyses are usually calculated for ion exchange purposes. The conversion factor to be used for the more common types of ions encountered in raw water are shown in Table 1.

TABLE 1—Factors Used in Converting Various Ions to Equivalent Calcium Carbonate

Cations	Factor	Anions	Factor
Calcium (Ca^{++})	2.5	Bicarbonate (HCO_3^-)	0.82
Magnesium (Mg^{++})	4.1	Carbonate (CO_3^{--})	1.67
Sodium (Na^+)	2.18	Sulfate (SO_4^{--})	1.04
Potassium (K^+)	1.28	Chloride (Cl^-)	1.41
Iron (Fe^{++})	1.79	Nitrate (NO_3^-)	0.81
Manganese (Mn^{++})	4.10	Silica (Si_2O)	1.67
Aluminum (Al^{+++})	5.56		

Impurities are generally expressed in terms of calcium carbonate as grains per gallon of water or ppm where one grain per gallon is equal to 17.1 ppm. However, the capacity of ion exchange resins is normally calculated on the basis of grains of dissolved ions removed.

Resin Capacity. The exchange capacity of the cation resin is usually in the range of 8 to 20 kilograins per cubic foot of resin expressed as calcium carbonate equivalent when sulfuric acid is used as the regenerant and 10 to 30 kilograins per cubic foot when hydrochloric acid is the regenerant. Weak base anion resins have a capacity for removing strong acids between 15 and 25 kilograins per cubic foot expressed as calcium carbonate equivalent. Similarly, the strong base anion resin has an

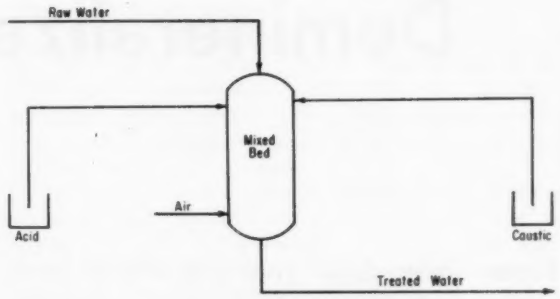

FIGURE 3—Type VI, Mixed bed system is best utilized on low alkalinity raw water with low solids content when a high degree of water purity is required.

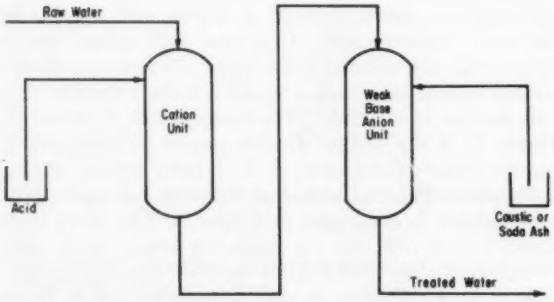

FIGURE 1—Type I, Two bed, cation—weak base anion system is used where silica reduction is not required and where carbon dioxide and low pH in the final water are not objectionable.

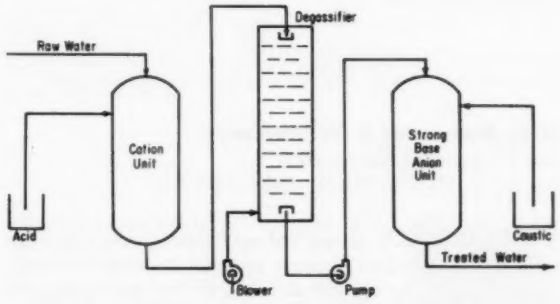

FIGURE 4—Type IV, Two bed, cation—degassifier—strong base anion system will produce treated water of equal quality as Type III at a lower operating cost but at higher capital investment.

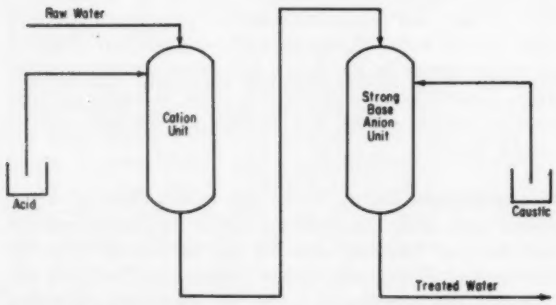

FIGURE 2—Type III, Two bed, cation—strong base anion system will reduce carbon dioxide to zero and silica to 0.1 ppm.

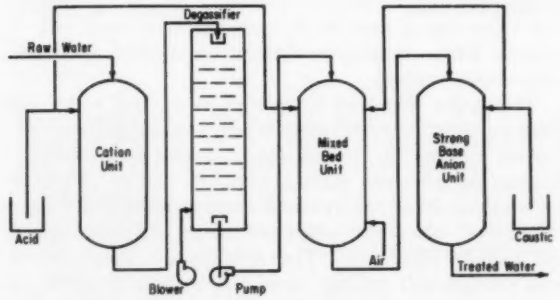

FIGURE 5—Type VIII, Cation—degassifier—mixed bed—strong base anion system is useful when treating raw water having a high alkalinity, silica, and solids content in varying concentration where ultra-pure treated water is required.

equivalent capacity varying between 8 to 18 kilograins per cubic foot of resin.

Water Quality. Demineralizers will produce waters of various quality depending upon the type of system employed and the water supply. The quality of treated water is often measured in terms of suspended solids, dissolved solids, micromhos, or ohms per cubic centimeter. Micromhos is used to define conductance of the water while ohms per cubic centimeter is a measurement of the resistance of the water. One micromhos conductance is equivalent to one million ohms resistance and represents approximately 0.5 parts per million dissolved ions as $CaCO_3$. Both measurements are for electrolyte or total ionizable dissolved solids of the water. Typical values showing the relationship between resistance, conductivity and total electrolytes present are shown in Table 2. When gases are present, they affect the resistance and must be removed or a correction must be made due to their presence.

Which System? For each set of conditions there is one best demineralization arrangement and extreme care should be exercised when selecting the type of system to be employed. This includes a complete evaluation of the raw water composition, amount, quality and type regenerants used, operating conditions and costs as well as the quality of water required in the final effluent. The following discussion gives a generalized picture of some common arrangements employed in commercial use along with pertinent comments concerning their application.

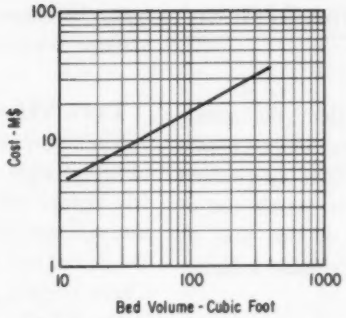

FIGURE 6—Use these approximate purchase costs for single ion exchange units without resins or regeneration equipment. Data based on single, rubber lined carbon steel units with resin bed of 27 inches and vessel straight height of 6 feet.

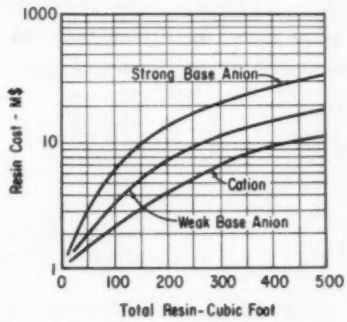

FIGURE 7—From this chart you can estimate cost of various ion exchange resins. Freight must be added to these costs.

TABLE 2—Relationship Between Resistance, Conductance, and Total Electrolytes Present

Resistance (Ohms)	Conductivity (Micromhos)	Electrolyte, as ppm $CaCO_3$ (Mixed Bed or Two Bed with Weak Base Anion)	Electrolyte, as ppm $CaCO_3$ (Two Bed System with Strong Base Anion)
3,000,000...	0.33	0.13	0.06
2,000,000...	0.50	0.20	0.10
1,000,000...	1.00	0.40	0.20
100,000...	10.00	4.00	2.00
50,000...	20.00	8.00	4.00

TYPE I: Two Bed, Cation—Weak Base Anion System. This system is used where silica reduction is not required and where carbon dioxide and low pH in the final water are not objectionable. It has the lowest equipment and chemical cost for this service. The effluent water usually has a conductivity range between 10 and 20 micromhos and may contain dissolved solids equivalent to about 5 ppm as calcium carbonate in addition to silica.

TYPE II: Two Bed, Cation—Weak Base Anion Followed by Degassifier. Generally used when it is desired to remove carbon dioxide and the presence of silica is not objectionable. The anion resin is regenerated with soda ash or caustic soda. The water effluent is similar to that obtained by Type I except carbon dioxide is reduced to 5-10 ppm and the pH of the final water is higher. In many instances, operating costs are up to 25 percent less than for Type I.

TYPE III: Two Bed, Cation—Strong Base Anion System. Essentially all ions may be removed by substituting a strong base anion unit for the weak base unit used in Type I. The treated water produced will generally contain less than 2 ppm solids as calcium carbonate equivalent including silica. Here the carbon dioxide content can be reduced to essentially zero and silica to a level of 0.1 ppm. Conductivity of the final water ranges from 5-10 micromhos. When treating raw water having a high alkalinity, the quantity of caustic used for regeneration can be reduced by placing a degassifier ahead of the anion unit to reduce the carbon dioxide load on the exchanger.

TYPE IV: Two Bed, Cation—Degassifier—Strong Base Anion System. This system is the same as Type III except a degassifier is added ahead of the anion unit to remove the bulk of carbon dioxide present. This arrangement will produce treated water of equal quality as Type III at a lower operating cost and at a higher capital investment. In addition, this system permits a smaller strong base anion unit to be used. It is usually economical to use this arrangement when treating high alkalinity waters where silica removal is desired.

TYPE V: Three Bed, Cation—Weak Base Anion—Degassifier—Strong Base Anion. Highly efficient when large quantities of all the more common anions (sulfates, chlorides, etc.), including silica are present. Water quality is about the same as that produced by Type III, but operating costs are lower. Here the weak base unit removes the bulk of total anions and the strong base unit has only to remove silica, residual carbon dioxide and small quantities of other anions. The weak base unit can be more efficiently regenerated and,

therefore, less expensive to operate than the strong base anion unit. The caustic soda used to regenerate the strong base unit can in many applications be used to regenerate the weak base unit. This double use of the regenerant makes the operation of this unit as economical as a two bed unit while producing a higher quality of water.

TYPE VI: Mixed Bed System. This type of system is best utilized on low alkalinity raw water containing fairly low solids content and where a high degree of water purity is required. Treated water from this unit can have a conductance ranging from 0.1 to 1 micromhos with silica reduced to a level of 0.02 to 0.15 ppm. However, silica removed is optional when using this unit. The mixed bed system has a low initial investment but operating costs are higher than multi-bed systems producing similar quality water.

TYPE VII: Cation—Degassifier—Mixed Bed System. When the alkalinity of the raw water is high, a cation unit and degassifier used ahead of the mixed bed unit will reduce the anion load and remove carbon dioxide thereby reducing both the size and operating cost for the mixed bed unit. This system is effectively employed where highest purity water with complete carbon dioxide and silica removal is required.

TYPE VIII: Cation—Degassifier—Mixed Bed—Strong Base Anion System. This system is useful when treating raw water having a high alkalinity, silica and solids content in varying concentration where ultra-purity treated water is required. The strong base anion unit then operates as a polishing unit with infrequent regeneration.

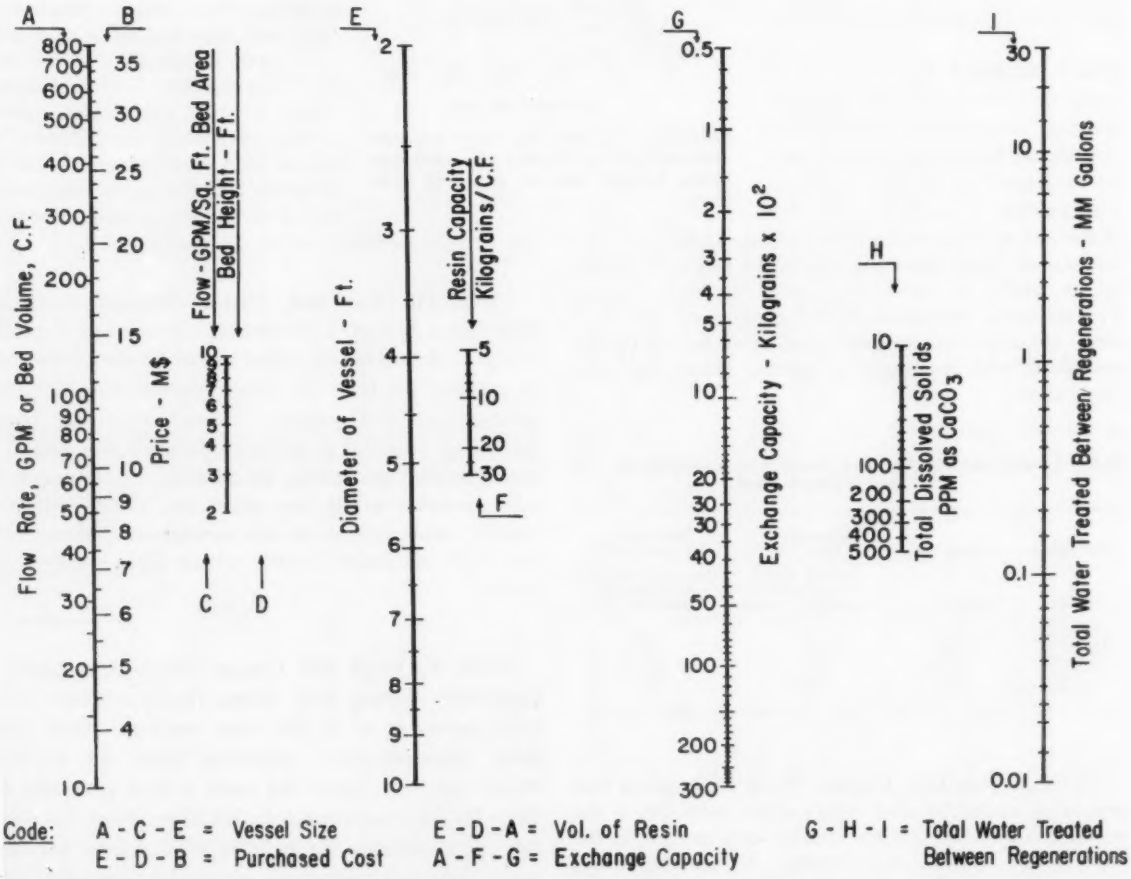
A
B
E
G
H
I
Flow Rate, GPM or Bed Volume, C.F.
Price - M$
Flow - GPM/Sq. Ft. Bed Area
Bed Height - Ft.
C
D
Diameter of Vessel - Ft.
Resin Capacity
Kilograins/C.F.
F
Exchange Capacity - Kilograins x 10^2
Total Dissolved Solids
PPM as $CaCO_3$
Total Water Treated Between Regenerations - MM Gallons
Code: A - C - E = Vessel Size
E - D - B = Purchased Cost
E - D - A = Vol. of Resin
A - F - G = Exchange Capacity
G - H - I = Total Water Treated Between Regenerations

FIGURE 8—Using this nomogram you can estimate the cost of mixed bed units without resins, unit size, total resin exchange capacity, and the total quantity of treated water produced between regeneration.

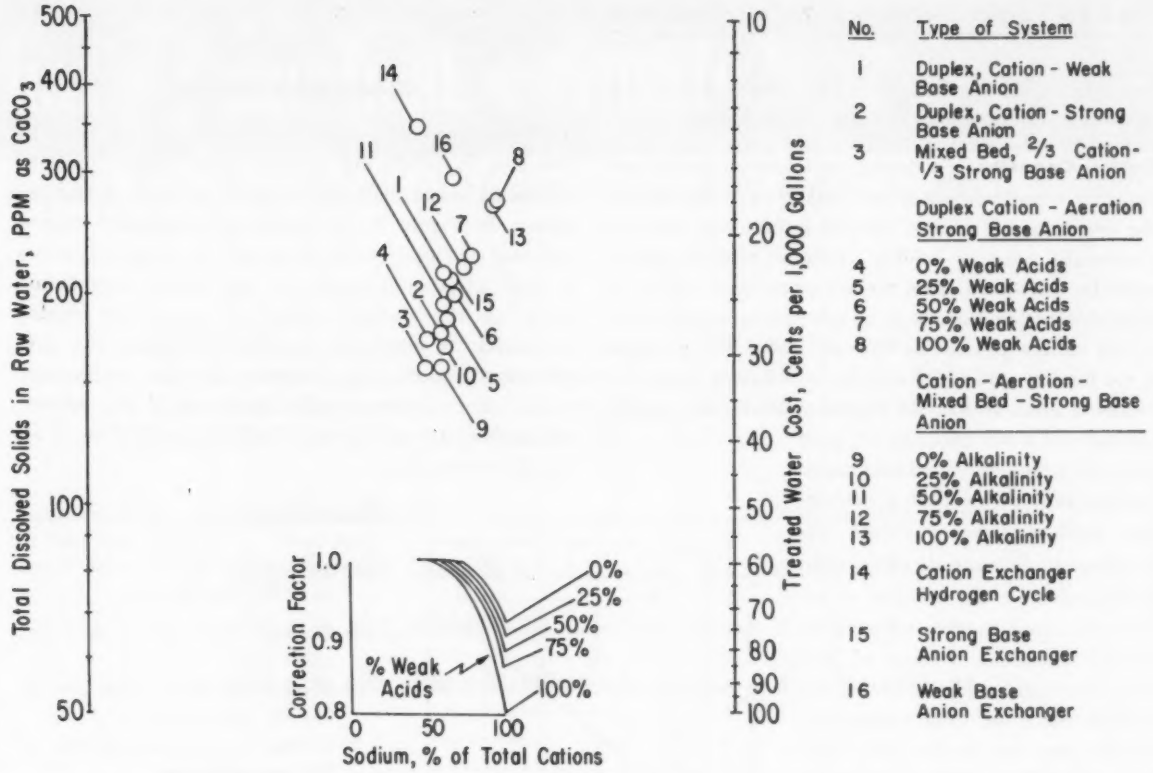

FIGURE 9—Estimated costs of producing treated water using usual combinations of exchange systems often employed are shown here.

INVESTMENT COST

The total number of different arrangements that can be employed are too numerous to be covered in a single article. However, this brief discussion of some of the basic arrangements should suffice when preparing preliminary capital cost estimates for water treating system. If other arrangements are required, their capital investment cost and estimated operating costs can be arrived at by building up the system using the basic building blocks given in Types I through VIII. The basic arrangements most often employed are illustrated in Figures 1 through 5.

Single Bed Units. The estimated purchased cost of single bed units without resins or regeneration equipment is shown in Figure 6. All costs are based on single rubber lined carbon steel units employing a resin bed depth of 27 inches and a vessel straight height of 6 feet. Other combinations of vessel dimensions yielding the same capacity will vary slightly in cost from those shown. The cost of ion exchange resins can be estimated from the data shown in Figure 7. Freight costs must be added to all prices to complete the purchased cost.

Mixed Bed Units. Figure 8 can be used to determine the cost of mixed bed units without resins, unit size, total resin exchange capacity, and the total quantity of treated water produced between regeneration. When the installation of a degassifier is required, its cost can be obtained from the price curve shown in Figure 11. The cost of regeneration equipment will run between 5 and 10 percent of the total purchased cost of the ion exchange units.

Weights and Installation Costs. Estimated weights of single ion exchange units complete with resins are shown in Figure 10. The installation cost for the various ion exchange arrangements will run about 25 to 35 percent of the total purchased cost of the units. This includes foundations at 5 to 10 percent while hauling, erection, and hook-ups amount to 15 to 25 percent depending on the type of controls, number of units, and arrangement employed. All the above prices are based on manually regenerated units. For automatic controls, add $1,500 to the purchased cost for units up to and including 5 feet in diameter. Approximately $2,000 should be used for units larger than 5 feet in diameter.

In addition, if a cubicle and centralized control unit is used, a figure of $2,500 should be included.

Cation Capacity. To determine hydrogen cation unit capacity when treating a particular raw water stream, the percentage alkalinity, percent sodium and the total theoretical mineral acidity (sulfates plus chlorides) must be calculated from the water analyses. Next the allowable cation leakage is established as a percentage of the cations present in the raw water. For example, if the final treated water effluent is to have a total ionic dissolved solids content of 4 ppm or lower, and assuming the raw water contains 200 ppm of total cations, the allowable cation leakage must be less than 2 percent. The level of cation leakage and to a degree, the capacity of the resin is controlled by the amount of excess acid used in the regeneration dosage. Practical dosages of 66° Baumé sulfuric acid will run about 0.35 pounds of acid per kilograin of cations removed by the resin. The acid efficiency usually varies between 25 to 35 percent and on average cation resin exchange capacity at this level of regeneration will be about 10 kilograins per cubic foot of resin. A similar approach is used for the anion unit where the total mineral acid content is calculated as calcium carbonate equivalent and the resin is regenerated with caustic soda instead of acid. If a degassifier is used ahead of the anion unit to reduce the carbon dioxide content, only the residual carbon dioxide in the deaerated water is used in the calculations.

The cation unit for systems other than a mixed bed unit must produce sufficient treated water to backwash regenerate, and rinse the anion unit. Secondly, the size of the cation unit must be large enough to handle the additional flow rate required for servicing and regenerating the anion unit. This is especially true where multi-bed cation units are followed by a multi-battery of anion units unless adequate storage of treated water is provided to handle these peak flows. Where small or single units are employed, it is customary to provide this tankage for treated water during the regeneration period.

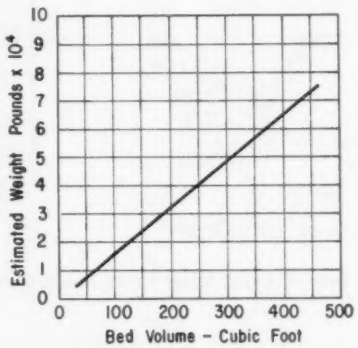

FIGURE 10—Use this chart for estimating shipping weight of single exchange units complete with resins.

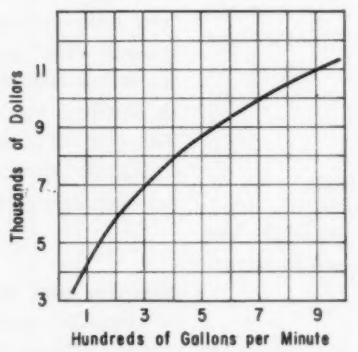

FIGURE 11—Use this price curve to determine degassifier costs. Data are for a forced draft type and include forced draft fan/motor, tower/catch basin, level control valve and controller, and two (2) pumps (stainless steel construction) and motors. For vacuum type deaerators, multiply costs by the following capacity range factors:

	Factor
50-250 gpm	2.0
250-650 gpm	1.5
650-1000 gpm	1.25

EVALUATION STUDIES

Preliminary estimates for evaluation studies covering the cost of producing treated water using the usual combinations of exchange systems often employed are shown in Figure 9. It should be emphasized that a rigorous economic analysis should be prepared before a final selection is made for any specific installation since all the variables involved cannot be readily covered in a simplified approach. However, the data presented is sufficiently accurate for most preliminary studies. For a more detailed treatment of this subject, the work of Monet,[1] Wirth,[2] McGill,[3] and Kabler, et al[4] should be consulted.

Cost Factors. The general operating costs used in deriving the cost to produce treated water were based on the following factors.

1. Cation resin cost at $22 per cubic foot.
2. Weak base anion resin cost at $35 per cubic foot.
3. Strong base anion resin cost at $62 per cubic foot.
4. Raw water cost at $0.10 per 1,000 gallons.
5. Electric power cost at $0.01 per 1,000 gallons of treated water.
6. 66° Baumé sulfuric acid at 6 pounds per cubic foot of resin and $0.015 per pound.
7. 76 percent technical flake caustic soda at 3.5 pounds per cubic foot of resin and $0.035 per pound.
8. Cation, strong base anion and weak base anion resins amortized over a useful life of 5, 2.5 and 1 million gallons of treated water per cubic foot of resin.
9. Average exchange capacity of 10 kilograins per cubic foot of resin.
10. Raw water flow rate of 6 gallons per minute per square foot of resin bed or vessel area.
11. Installed equipment amortized in 10 years.
12. Operating labor costs at $2.50 per hour.

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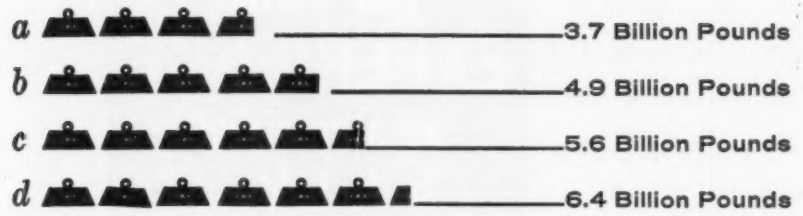
[1] Monet, C. P., Chem. Eng., 57, No. 3, March 1950, Page 106-7.
[2] Wirth, Louis, Jr., Combustion, May 1954.
[3] McGill, J. F., Power, 98, July 1954, Page 79-81.
[4] Kahler, F. H. and Reents, A. C., *Chemical Engineering*, January, 1957, Page 206-10.

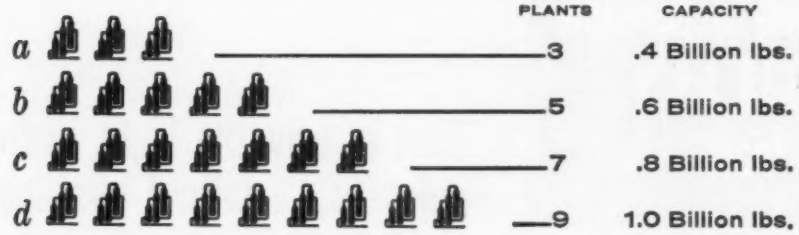
what's your best estimate?

...a quiz for Petrochemical Executives who want to keep posted

QUESTION 1. In 1959, 28 plants in the United States were producing ethylene—the hydrocarbon intermediate which is way ahead of all others both in quantity produced and in versatility. What was the estimated total U. S. capacity for this valuable chemical in 1959?



QUESTION 2. How many of the U. S. ethylene plants were designed, engineered and constructed by the Lummus Company?



ANSWERS: 1. *The answer is (c)—5.6 billion pounds, according to* Chemical Week's *Report on Ethylene, May 9, 1959.*

2. *Again the answer is (c). In the last 10 years Lummus has 7 Ethylene plants to its credit in the U. S. alone with a combined capacity of .8 billion lbs. Lummus' world-wide total is 13, with a combined capacity of over a billion pounds per year. For ethylene projects, or any type of process plant, call on Lummus' 50 years of experience in design, engineering and construction.*

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WHY PROBLEM-SOLVING BETWEEN GROUPS SOMETIMES FAILS

APPLIED GROUP DYNAMICS

Why do labor-management negotiations sometimes break down? Why can't two groups within a company agree on an issue? One answer is that most spokesmen are committed people—individuals who would rather remain loyal to their group's position than solve the problem

Robert R. Blake and Jane S. Mouton
The University of Texas, Austin

WHEN DIFFERENT GROUPS meet to resolve their differences, it is usually done by having representatives of the competing groups act as spokesmen. If representatives are unable to agree, the services of an arbiter frequently are sought. These same general proceedings are followed in a management development laboratory, with the dynamics of representational behavior analyzed from the direct experience of participants.

Electing a Spokesman. At this stage in the evaluation of intergroup competition, each group elects a spokesman who is to interact and negotiate with the spokesman from the adversary group to determine which one is the winner and which the loser. The election is conducted by a ranking system so that each person evaluates himself as well as all other group members from the standpoint of adequacy to serve the group as its spokesman. Since data characterizing individuals, indicating how each person is seen by his peers, are available from other sources, it is possible to study the personal characteristics of those who receive a high number of spokesman choices with these receiving a low number of nominations. The results are in Figure 17.

Figure 17 shows that high ranking spokesmen are seen to have quite different characteristics from those not chosen to be spokesmen. They are seen, for example, as offering constructive evaluations, finding ways to be helpful, assuming the leader role, contributing to problem solutions, expressing themselves clearly and concisely, and so on. On the bottom of Figure 17 we have listed the characteristics that fail to distinguish high from low ranking spokesmen.

Many of the personal characteristics often thought to be important to success in becoming a representative turn out to be irrelevant. Examples are: opinionated rather than factual, mannerisms, self-repetition and so on.

Summarizing the general picture, it seems as though strong, active, participating, capable people "come to the surface" under elective conditions! Here, in a word, is the strength of democratic institutions as far as ingroup aspects are concerned. People seem to have "good sense" regarding those who can represent them in a satisfactory manner. Yet as you will see later, individuals who are constructive and helpful on an ingroup basis are incompetent to adjudicate differences between their own and contesting groups.

A suggestive implication, as is true in many refineries, is that some of the best foremen and area supervisors are persons who previously have held union offices. Management may be better able to "see" a practical man's human skills, once they have been revealed through the operation of democratic procedures!

Negotiations by Representatives. The spokesman who is selected by each group explains and clarifies his own solution in response to questions from members of the competing group. The explanation and clarification phase lasts for an additional two or three hours. The role of the spokesman is critical at this point for his group expects him to defend them from attack and to

Items that discriminate

- Offers a constructive evaluation as needed
- Finds ways to help the group
- Assumes leader role
- Contributes to problem solution
- Poses the problem for the group to discuss
- Expresses himself clearly and concisely
- Summarizes when we stand on an issue
- Gives suggestions about how we should proceed
- Dominates group effort
- Pushes the group to stay on the central agenda

Items that do not discriminate

- Expresses personal needs to group
- Optionated rather than factual
- Mannerisms diminish effectiveness
- Views only from own point of view
- Repeats himself
- Accurately understands behavior of others
- Senses when to talk and when to listen
- Interest and involvement fluctuate
- Sees general problem as well as specifics
- Makes others feel at ease

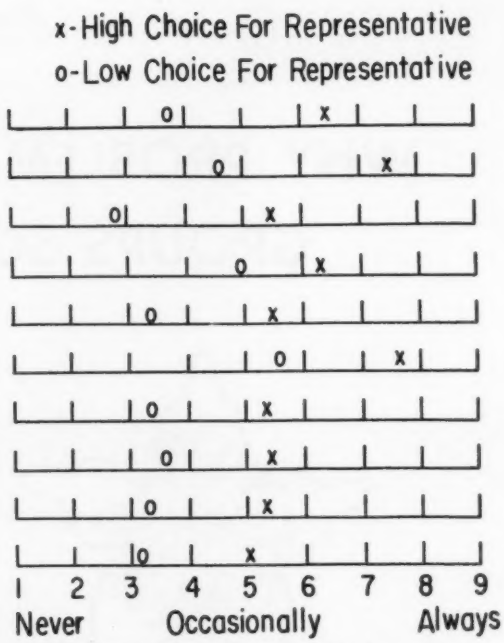

FIGURE 17—How members describe those they want to represent them.

lead the offense against the other group. Thus the interaction, rather than leading to resolution, results only in the intensification of competition, the elevation of feelings regarding the quality of one's own group solution, and in the devaluation of the solution of the competing group.

Then representatives meet. Most frequently their interaction develops into a 1/1, or win-lose contest, with each representative maintaining his group's position while attempting to provoke the other representative to capitulate. The person who exerts influence on the opposing representative and in doing so obtains acceptance of his group's position may be accorded a hero reaction within his group for bringing it victory. On the other hand the representative who relinquishes his group's position, thus giving victory to the opposition, is subject to being treated as disloyal or as traitorous by members of his own group.

Spokesmen are Committed. Since neither representative wants to lose status, it is rare that a spokesman capitulates. The data in Figure 18 show that only two out of 33 representatives in this type of competition have capitulated. They were booed, ostracized and treated as "traitors." The results indicate with great clarity that spokesmen are committed people—individuals who would prefer to be "loyal" than to solve the problem. Could these relationships be basic for understanding vituperative accusations and counter accusations between McDonald representing the Steelworkers of America and Cooper representing the steel companies in the hopelessly deadlocked labor management controversy of 1959?

The existence of two or more groups having sufficient cohesion to permit them to engage in group action is essential in organizational life. Without such social units, no action on the part of a representative on behalf of a group is possible. Given these conditions, however, interactions between groups become necessary in order for them to engage in correlated activities. If these conditions prevail, however, a "hero" or a "traitor" reaction is likely to develop toward a representative. If he sticks by his groups position fending off attack from all sides, he gets a "hero" reaction. If he "capitulates" giving victory to the other group, he is treated as a "traitor." What are the precise conditions required to arouse a hero or traitor reaction?

1. Intergroup Competition. A first requirement is a situation which includes two or more groups in functional contact and competing with one another through the interactions of representatives.

2. Group's Success Rests with Representatives. A second condition is for the fate of the group to rest in some measure on the reactions of representatives as they operate in contact with the opposing group.

3. Representatives Regarded as "Trustworthy." A third consideration is for representatives to be seen as trustworthy and loyal group members. They are expected to side with their own group rather than to submit to pressure exerted on them by the opposing group, even though their logical obligation is to find the best of the two solutions.

These three factors seem necessary for the emergence in experience of either the "hero" or "traitor" reaction. However, a significant additional factor must be present to determine which reaction develops. It involves how the representative responds to pressures to submit while in functional contact with representatives of the opposing side.

Hero. If the representative of one group submits to pressure while the representative of the other remains loyal and thereby attains victory, the psychological experience of the winning group members toward their representative is, "Confronted with pressures to submit, he stood firm and *won*. He is a *'hero'*."

Traitor. If the representative submits to pressures, renouncing the position of his own group with the result that his action leads to the failure of his group, the reaction experienced toward him is, "Confronted with pressures to renounce us, he betrayed us and we lost. He is a *'traitor'*."

Specific Applications. The way of thinking above can be applied to analyzing reactions toward historical figures as well as to problems confronting organizations where competing groups seek to solve difficulties through representational systems. One application is with respect to the traitor reactions to GI turncoats during the Korean conflict. A second is in an analysis of reactions to the heroic behavior of Alvin C. York in World War I. At this point, it seems worthwhile to step away from the industrial setting in order to get a more general picture of the high importance that should be attached to the hero and traitor reaction. Other implications are with respect to industrial organization, labor and management, and international negotiations.

GI Turncoats. The circumstances confronting GI turncoats in Korea included features described here as components in the "traitor" reaction. Two groups were in competition, and to a degree, the fate of one group can be regarded as resting on the loyalty of its prisoner "representatives" who were in contact with members of the opposing group. Furthermore, they were expected to be trustworthy and to resist pressures to renounce their ideological positions. Certain representatives submitted through signing false confessions, etc. They were contributing to the jeopardy of their group. They were traitors.

Prisoner representatives who resisted, who refused to renounce, were loyal. They acted with honor, but even then they were not accorded the reactions of heroes. Had they been able to shift the position of the representatives of the opposing groups to that of their own group, they would have been accorded the designation of heroes.

Sgt. Alvin C. York. One of the heroes of World War I was Sgt. Alvin C. York. He dealt with 132 Germans singlehandedly and he was accorded a hero's welcome for having done so. As a trustworthy representative of one group he was confronted by representatives of an opposing group. Rather than submitting to pressures in the situation he resisted with skill and fortitude. He exerted pressure on them and "won." The factors in this situation were strikingly similar to just described as being necessary if the reaction of "hero" is to be experienced.

Meetings of representatives of departments frequently are similar to those just described. Two or more departments may be in competition over such issues as budget allocation, manpower needs and so on. A single solution has to be achieved through the interaction of representatives of departments.

When members who have participated in developing their own group's proposal act as representatives, they are then faced with the situation just described. To resist pressures in meetings with other representatives and win by gaining acceptance of one's own group proposal over the proposals of the opposing groups, is to be a loyal representative and a hero of the department. To shift toward an opposite point of view than the one formerly accepted in one's own group is to appear in a "traitor" role.

Labor-Management Relations. Labor and management negotiations frequently parallel the one outlined above as important in producing reactions of hero or traitor. Two groups are in competition, with success of either resting on the skill of its representatives in shifting representatives of the other group toward their own point of view. Furthermore, representatives are seen by their group as trustworthy and reliable and are expected to remain loyal to the position supported by their own group.

If representatives of one side skillfully exert influence and shift those of the other away from a position formerly held, they generate positive feelings toward themselves in their own group for having done so. Those who submit and permit themselves to be moved, on the other hand, are seen by their group as having "let the group down." It is understandable why negotiations are likely to end in deadlock with representatives unable to agree on even small issues, for it may be more important to be loyal and deadlocked than to shift and allow the other group to "win" at the possible expense of one's own membership position.

The situation described here also permits clarification of difficulties of negotiation among international bodies.

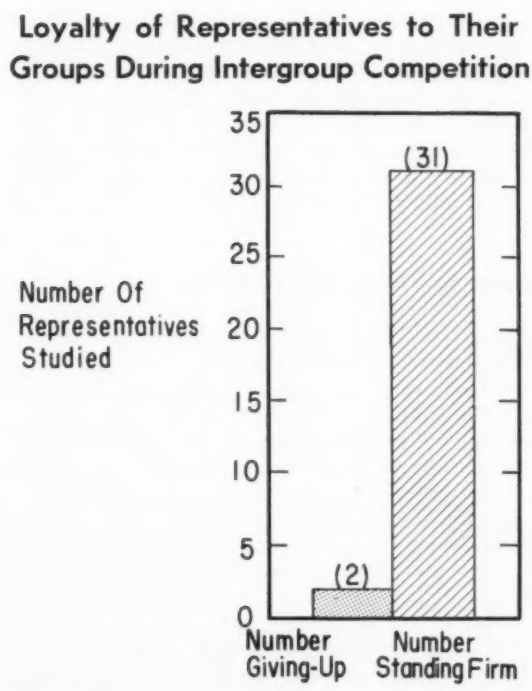

FIGURE 18—Since neither representative wants to lose status, it is rare that a spokesman capitulates.

Competing groups with incompatible points of view are represented by trusted members. Resolution of differences then is rendered particularly difficult. Deadlocks between representatives frequently result in preference to "giving ground" and facing rejection by the losing group.

Deadlock. "Deadlock," an 0/0 power situation, is one result of the traitor threat. If a representative cannot win, through deadlocking the issue he can avoid losing. Through deadlocking, a traitor reaction can be avoided, but representatives of both sides stand to suffer reduction in membership status relative to their increased power accompanying victory. Another alternative to defeat is "compromise"; give as little as possible and get as much, or create the appearance that both sides have yielded some, but with neither suffering defeat. Unfortunately such compromises often may be mechanical and brittle, constituting artificial solutions rather than real resolutions.

When negotiations take a win-lose turn, as often happens when preferred positions constitute public standards announced in advance, then quest for resolution by representatives is replete with obstacles. The core of the difficulty is that representatives are "committed" people. From the standpoint of their own group membership they are not free to act in accord with *fact* or even to engage in compromise, if to do so would be interpreted as defeat.

To a degree the limitations noted here may be reduced when representatives are freed to negotiate without prior instructions. Even then, however, they usually are "expected" to act in certain ways even though formal instructions have not been placed on them.

The critical limitation in seeking resolutions through representatives seems to be in the "conflict of interest" aspect. For the representative to suffer defeat may be for him to place his membership status in jeopardy while by gaining victory he may enhance his membership position. In the negotiation situation though, logical considerations may require that the representative renounce his group's prior position in order to gain a valid resolution of an intergroup problem. Where there is conflict of interest, the situation is such that the ingroup loyalty can overwhelm logic.

Use of Arbiters. When negotiations by representatives fail, arbiters may be brought in to break a deadlock and to decide the way out. The situation changes from an 0/0 deadlock relationship between the two representatives to a 1/0, with the arbiters having the 1 and the two groups relinquishing all power over the outcome. Since arbiters hold membership in neither of the competing groups, they can be "fair." The Supreme Court and federal and state legal systems all are based on gaining resolution through the use of neutrals. Because of the arbiters' position, contestants are expected to accept the outcome as an impartial one.

But do they? The answer depends on where you sit. It is likely to be "Yes," if the decision favors your group; "No," if it goes against the position you embrace. Listen to the following remarks. They are reactions toward an arbiter from those defeated by his decision.

"The arbiter is biased, unfair and incompetent . . . he has no grasp of the problem . . . he does not possess the intelligence prerequisite to be fair and unbiased . . . he doesn't seem to know too much about the subject . . . he didn't take enough time."

In other words, when members are committed to a position, and an arbiter decides against it, either the group is wrong or the arbiter is wrong. In their initial reactions, group members have little doubt as to which; it is the arbiter. (Results from several sources suggest that the stronger the commitment of a group to its solution, the more relevant the problem to the life of the group, and the more cohesive the group, then the greater the negative reactions toward the arbiter whose decision defeats them.) Even though obligated to accept the verdict, attitudes remain more or less consistent with the convictions held prior to the rendering of the judgment.

Delayed Reaction. When intergroup competition has been generated for study purposes under laboratory training conditions, with resolution of the conflict placed in the hands of an arbiter, a delayed reaction of considerable importance has been noted among members within some defeated groups. Though the initial reaction in the defeated group toward the arbiter is, "It's the *arbiter* who is at fault," a delayed reaction among some members is, "It's *our group* which is at fault."

Such a reaction arises among the members who were the least committed to the group's position *before* the issue was submitted for arbitration, or among those who prize their membership highest. Rather than venting their frustrations from defeat on the arbiter, they discharge it by attacks on the other members. A consequence is that the group tends to splinter, to lose its former degree of cohesion, and to disrupt.

When the arbiter renders a verdict favoring a group's position, two things are evident. The arbiter is experienced as being fair and unbiased all right, because the judgment he proclaims "only proves that we were right in the first place." He is experienced as being a good arbiter because he sees the situation as members themselves see it. "If there was any doubt in our minds before, his ruling eliminated it; now we know we're right."

Reactions to Victory and to Defeat. Following the intergroup competition, one group finally emerges as victorious. The other is vanquished. Victory and defeat produce important different reactions.

A victorious group retains its cohesion. Now the group is fat and happy. Group members sit and pat one another on the back. Winners do not feel tension, a fighting spirit, or competitiveness. Instead, they play. They cooperate with one another, but they avoid work. Why is it that victory leads to a fat and happy type of social atmosphere? Is it because the glow of victory turns people away from the problems and frictions they would face if they were to try to deal with them? It's much nicer to feel the glow of power and success than to suffer the pangs of anguish associated with the lean and hungry digging activity of a hard working group.

In the defeated groups an opposite set of reactions is apparent. There is a compulsion among members of

defeated groups to place responsibility for their fate either in terms of the individuals who led it to defeat or to the faulty problem-solving that made it difficult for the group to develop a superior solution of the problem with which it was confronted.

The group splinters, members fight among themselves, they argue as to why they fell, and they try to identify who led them into it. Members challenge the old leadership. Soon it becomes apparent that the former leaders have lost some of their strength, at least for a while. They no longer seem to be so trustworthy as they were thought to be prior to leading the group into defeat.

Are these patterns of reaction unique to a management development laboratory? Indeed not! They are known to be present in the interactions of many segments of an organization, as well as in labor-management situations, where one side is clearly victorious and the other side vanquished.

Applied to Oil Companies. One highly instructive example of the negative effects of success or victory and of the positive effects of failure or defeat can be taken directly from within the oil industry. Many large oil companies have Research Divisions. The only justification for a Research Division is to bring about change in operating segments of the company. What do research people say about problems of getting their ideas accepted? They say it's easiest in *new* units of the company, which are not tradition-bound, or in units which are in economic difficulty, sitting on the brink of disaster.

Such units are "lean and hungry," ready to go. It is most difficult to get acceptance of research ideas in old segments of the company, particularly those that continue to do well in terms of ringing the bell on the cash register. The reason is obvious. Why should they change? They have an established pattern of success.

Success can blind an individual or a group, or an organization to new patterns, new ways of doing things, and so on, to the point where success is lost, with change forced by disaster and economic necessities, rather than by foresight and planning. Success is the world's most expensive luxury, unless you know how to deal with it. Most groups don't! Yet there is no reason why success should lead to complacency, if you understand the relationship between the two!

What is the corrective antidote to success? To wait until failure strikes? No! Even though this formula seems to be the one that reoccurs, sometimes leading to the failing of successful groups, it is neither necessary nor adequate. Too frequently failure is the *end* of a successful organization. The legions of Caesar, and of a thousand other units, tell the story of groups which, once successful, have been unable to recover when confronted with failure.

The effective antidote to success is *insight* into the dynamics accompanying both victory and defeat. Understanding the stultifying results of success can be used to counteract such effects. Defeat which causes an organization to collapse likewise can be avoided. But the only sound and true course to insight is constant study within the organization by using feedback to reappraise the situation and to continuously reformulate goals.

Only through the steady, persistent reassessment of aims and objectives is it possible for a work unit to keep itself lean and hungry, digging to accomplish more than was attained by a previous success. When a group is able to accomplish such results, it is truly mature; able to withstand victory or defeat and to plot a straight course of progress.

No facet of life is more instructive for understanding why people react as they do than is intergroup competition. Any manager, whether foreman or president, is enmeshed in intergroup frictions either as a member of one or another work group, or as the man in the middle, between them. A manager needs to know a great deal about these problems and how to manage them effectively. The company that takes human energy that is being wasted in fruitless contention between groups, and channels it toward constructive corporate objectives will have found that proverbial "better mouse trap."

TO BE CONTINUED

About the Authors

Dr. Robert R. Blake is a professor at The University of Texas where he does teaching and research concerned with industrial social psychology in the field of management development through applied group dynamics. Dr. Blake received his B.A. degree from Berea College in 1940, his M.A. degree a year later from the University of Virginia and his Ph.D. degree in 1947 from The University of Texas. After receiving his Ph.D. Dr. Blake remained at The University of Texas, and in 1949 journeyed to England for a year where he was lecturer at the University of Reading and honorary clinical psychologist, Travistock Clinic, London. Then in 1950 he spent a year as lecturer and research associate at Harvard. Listed in *American Men of Science,* Dr. Blake is presently a director of the Policy Planning Board of the Human Relations Training Laboratory; on the Board of Trustees of the Institute of General Semantics; a member of the National Training Laboratories, American Psychological Association, Association for the Advancement of Science and many other professional societies. He is also a management consultant in industrial social psychology to many major oil and chemical companies.

Dr. Jane S. Mouton is an assistant professor at The University of Texas where she does teaching and research in social psychology basic to industry. Dr. Mouton received her M.S. degree from The University of Texas in 1950 with a major in mathematics and physics; her M.S. degree in 1951 from Florida State University and her Ph.D. degree in social psychology in 1957 from The University of Texas. Since that time she has been assistant professor, instructor and social science research associate. Dr. Mouton is a member of the American Psychological Association, American Society of Group Psychotherapy and Psychodrama, Interamerican Society of Psychology and many other professional and fraternal societies.

A Short Course on Labor Law

Here's an interesting and informative discussion of how the Federal government got into the labor relations picture, and which parts of our Constitution are used to justify Federal labor legislation

G. T. Medlock and R. D. Stevens
Management Consultants
Washington, D.C.

AS AN ENGINEER you could not hope to understand present-day labor relations including the various labor laws if you did not first acquire a working knowledge of our Constitution. You realize, of course, that in our country both the State and Federal law are based upon our Constitution and, this applies to labor law as well as to any other. In other words, no State or Federal labor law could long exist if it violated our Constitution. So, it becomes clear that to understand labor rights we must start with the Constitution.

Labor relations and labor law are not mentioned in a single section of our Constitution. Judging from this you might conclude that the Federal government has no authority to regulate labor relations or enact labor laws. But of course that is not the case.

The Constitution. You understand this better if you know something about the meaning and nature of Amendment 10 of our Constitution. It provides that, "The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people." In other words, the Federal government has only delegated powers and the State "or the people" have all the rest—the residual powers.

Since our Constitution says nothing about the Federal government having any authority over labor relations, you might conclude that the framers of our Constitution never intended that it should have any such power. This may have been the case since until the 1880s the Federal government stayed out of labor relations even though some labor legislation was passed before that time by the State legislatures.

By this time however, some people believed that the Federal government should enter the field of labor relations and, of course, efforts were made to find a way for it to do so under our Constitution. You will understand how it was possible for the Federal government to enter into this picture if you go back to the early days of our Constitution. Shortly after its adoption, two schools of thought developed as to how it should be interpreted.

Interpretation. One group held that our Constitution should be literally interpreted, that is, if the power of the Federal government was not found in specific words of our Constitution, then it had no such authority. As applied to labor, it was construed that since our Constitution said nothing about the Federal government having any control over labor relations, then it had no such power.

The other group, of course, differed. They held that power and authority might be implied from direct grant of power. This is referred to as the "Doctrine of Implied Power!" It was held that, while our Constitution did not specifically grant the Federal government the power to enact labor laws, it did, for instance, give it complete control of interstate and foreign commerce. And since it had this specific grant of power, it was implied that it could regulate and control every phase of interstate and foreign commerce, including labor relations.

Thus, since the 1930s the views of broad constructionists have seemed to prevail sufficiently for the Federal government to enact many monumental labor laws.

Applying the Articles. There are several articles which have been interpreted as applicable to the field of labor relations. For instance the First Amendment reads: "Congress shall make no law respecting an establishment of religion, or prohibiting the free exercise thereof, or abridging the freedom of speech or of the press, or the right of the people peaceably to assemble, and to petition the government for redress of grievances."

This Amendment seems to limit Congress, however it does not apparently place such limitations upon the States. Thus under the Constitutional right of free speech, labor unions claim the right to picket an employer's business and carry signs to inform the public in what respect the employer is alleged to be unfair.

The Fifth Amendment relates to a number of matters but the part that particularly concerns you reads: "Nor shall (any person) be deprived of life, liberty, or property, without due process of law." This Amendment, seems to limit the Federal government, and apparently, means in the field of labor legislation, that Congress may not enact any law that might, in any way, deprive a person of his life, liberty, or property.

You should understand, however, that "property" is the word that has become really significant. The courts have interpreted contracts, or, the right to make contracts as property rights, and, therefore, covered by the due process of law clause in the Fifth Amendment.

Furthermore, the 14th Amendment provides: "No State shall make or enforce any law which shall abridge the privileges or immunities of citizens of the United States, nor shall any State deprive any person of life, liberty, or property without due process of law, nor deny to any person within its jurisdiction the equal protection of the laws." This Amendment apparently limits only the States. Under it, no State may pass any law that would, in any way, take life, liberty, or property of any person without due process of law.

Legislation. When we specifically speak of labor legislation, however, we must consider Article 1, Section 8, of the Constitution. It provides that, "Congress shall have

LABOR LAW QUIZ

How many questions can you answer? . . . Rate yourself . . . What is your score?

	True	False
1. Many of our Federal labor laws have been passed under the authority of the Commerce Clause.	____	____
2. The First Amendment of our Constitution guarantees freedom of speech, press and assembly.	____	____
3. Our Constitution provides that the Federal government may pass laws concerning labor relations as affecting interstate commerce.	____	____
4. The Federal government has only delegated powers and the States have residual powers.	____	____
5. The U.S. Department of Labor was created in 1913.	____	____
6. The NIRC was passed in 1933.	____	____
7. The NLRA was passed in 1935.	____	____
8. Unfair labor practices apply only to employers.	____	____
9. The LMRA says the expressing of any views, arguments, or opinions, or dissemination thereof, does not constitute an unfair labor practice if such expression contains no threat of reprisal or force or promise of benefit.	____	____
10. The LMRA requires that a collective-bargaining contract be put into writing if either party requests it.	____	____
11. The Constitution says Congress has the power to regulate commerce among the several States.	____	____
12. An employer is no longer required to bargain with representatives of supervisors under the LMRA.	____	____
13. An employer has a right to petition the NLRB for an election to determine bargaining agent.	____	____
14. It is not an unfair labor practice for a union to refuse to bargain with an employer.	____	____
15. The right to strike is prohibited by the LMRA.	____	____
16. The FLSA applies to employees engaged in intrastate commerce.	____	____
17. An executive, administrative or professional worker is exempted from overtime pay beyond 40 hours weekly.	____	____
18. Employers must keep time and payroll records under the FLSA.	____	____
19. The national minimum wage is 75 cents per hour.	____	____

Answers on Page 397

the power . . . to regulate commerce with foreign nations and among the several States and with the Indian Tribes . . ." This is the well-known commerce clause, and that it has been under this clause that Congress has been able to enact most of its labor legislation.

It seems rather strange that a clause of so few words could be so significant. Yet, this clause has been the Constitutional basis and authority for the enactment of labor laws. Under it Congress has been able to regulate such matters as hours, wages, child labor, collective-bargaining, and general working conditions of every firm or industry in commerce or in the production of goods for commerce.

In addition, Article 1, Section 8, has a clause which provides that, "The Congress shall have the power to lay and collect taxes, duties, imposts, and excises, to pay the debts and provide for the common defense and general welfare of the United States . . ." This also has opened wide areas for Congress in legislation in the field of labor relations.

Looking Back. Let's take a quick look at the history of recent labor legislation. During the early years of the 1930s the Federal government re-entered the field of labor relations through the passage of the National Industrial Recovery Act in 1933. It was not an Act which dealt with labor relations alone—it was much broader and more comprehensive because it dealt with many segments of our competitive, free enterprise system.

The Social Security Act of August 14, 1935, as amended provided for two nationwide systems of social insurance to wage earners against loss of income due to unemployment, old-age, disability, and death.

The National Labor Relations Act of 1936 was a comprehensive labor law. It was amended by the Taft-Hartley provisions of June 23, 1947, which guarantees the right of employes to organize and bargain collectively with their employers, or to refrain from any or all such activities.

The Fair Labor Standards Act, or the Federal wage-hour law, as many call it, is one of the most monumental labor laws ever enacted by Congress. It has been in effect since June 25, 1938, as amended, and sets minimum wages, overtime, exemptions, and child labor standards which apply only to employes engaged in interestate commerce or in the production of goods for interstate commerce, including any closely related process or occupation directly essential to such production.

The Walsh-Healey Act was passed June 30, 1936 and sets the basic labor standards for work done by employers engaged on Federal government contracts exceeding $10,000 in value for materials, articles, supplies and equipment.

A new era in labor relations has occurred as a result of the passage of the Labor-Management Reporting and Disclosure Act of 1959. It provides for the reporting and disclosure of certain financial transactions and administrative practices of labor unions and employers to prevent abuses thereof.

Departments. The U.S. Department of Labor plays a major role in the field of labor-management relations, but not all labor activities are centered in this Federal department. It came into being on March 4, 1913, and today, the Department of Labor has many operating bureaus.

You may want to get a copy of its official publication, *Federal Labor Laws and Agencies.* This is a layman's guide under one cover which can be used as a quick reference to labor laws and regulations.

The National Labor Relations Board administers the present Taft-Hartley Act. It publishes the booklet, *A Guide to the NLRA—Procedures and Practices.* This, too, is a layman's guide for those who are responsible for collective bargaining negotiations.

The following check-list is a graphic way of re-evaluating your own knowledge of labor relations. You should be able to answer all these questions. To test yourself on labor law, put a check mark in the proper place with a "True" or "False."

You must remember that all our State and Federal labor laws including administrative rulings must conform to the requirements of our Constitution. Thus, in the final analysis, the courts makes the last decisions.

Test Yourself on Labor Relations

No. 1. Wants Union Present

Charlie Propet was an 8-year man. One day his foreman asked him to do a job Charlie felt was not within his classification.

He balked. "That's not my job. Check my classification and you'll see," he said.

The foreman left to check the job description. When he returned he ordered the employe to do the work because no one else was around to do it. Charlie still wouldn't budge. The next morning, when Propet came to work, he was told to report to the plant supervisor's office. "Where's my shop committeeman? I won't go unless I have the union with me."

"You go in alone—or you go home," was the foreman's answer. Charlie went home. The union took his situation up to arbitration. It argued:

1. The contract says that grievances shall be discussed by the employe and his representative and management.
2. Charlie had a right to have the union present in the supervisor's office because he anticipated discipline.
3. Management has no right to talk discipline with an employe without the union being in on it.

The company said:

1. Management has a right to confer with workers any time.
2. There was no formal grievance filed so the union was not necessary in this discussion.

Test yourself:

Was the company: RIGHT ☐ WRONG ☐

No. 2 Entitled to Recall?

Bill Calton was on layoff due to lack of work. Meanwhile, at a union meeting he was elected a member of the bargaining committee. The Union demanded that he be recalled to work at once. The reason: the union contract had a "super-seniority" clause. This meant union officers have top seniority.

Management refused to recall Bill. It held that when he was laid off he was not a union officer and that he cannot get special privileges off the job. Said the union: His election to union officership was the union's business, not management's. By denying Bill his job, the workers are denied representation.

Test Yourself:

Was the union: RIGHT ☐ WRONG ☐

No. 3 New Workers for New Products?

When the company launched a new product, it wrote out detailed job descriptions for those who were to work on the new jobs. One requirement was that each employe who applied must pass a qualifying test. A number of employes failed it. The company then filled the new jobs with outside workers. The old-timers protested:

1. We must be given a chance to work on the new jobs. The work isn't very different from what we've been doing.
2. You never before used tests. Why start now?
3. What good is seniority if the company can skip over us like this?

Management contended:

1. These are newly created jobs and the qualifications are much higher for them.
2. We certainly can give tests if we want to. How else can we judge ability and potential?
3. The senior employes do not have the experience for handling these new tasks—so we do not have to use their background with the company as a basis for selection.
4. Seniority is okay only if the employe actually has the ability to do a promoted job.

Test Yourself:

Was the company: RIGHT ☐ WRONG ☐

Answers on Page 400

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Oleum H_2SO_4 + SO_3	Liquid	15% SO_3 (103.4% H_2SO_4) 20% SO_3 (104.5% H_2SO_4) 65% SO_3 (114.6% H_2SO_4)	Drums Tank Trucks Tank Cars Tank Barges	Sulfonation.
Sulfan® Stabilized SO_3	Liquid	99.5% SO_3	Drums Tank Cars	Sulfonation.
Hydrofluoric Acid, Anhyd. HF	Liquid	99% HF	Cylinders Tank Cars	Alkylation.
Muriatic Acid HCl + Water	Liquid	18°, 20°, 22° Be (27.4% to 34.1% HCl)	Carboys Tank Trucks Tank Cars	Acidizing and isomerization.
Fluosulfonic Acid HSO_3F + Water	Liquid	98% HSO_3F	Drums Tank Cars	Alkylation and polymerization.
Boron Trifluoride	Gas	99% BF_3	Cylinders	Alkylation and polymerization.
Boron Trifluoride	Liquid	48% BF_3	Drums Tank Trucks Tank Cars	Alkylation and polymerization.
Boron Trifluoride	Liquid	26% BF_3	Drums Tank Cars	Alkylation and polymerization.
Sodium Metasilicate, Crystal $Na_2SiO_3 \cdot 5H_2O$	White Granules	29.0% Na_2O	Bags Fibre Drums	Detergents.
Sodium Metasilicate, Anhyd. Na_2SiO_3	White Granules Powder	50.5% Na_2O	Bags Fibre Drums	Detergents.
Sodium Silicate $Na_2O \cdot XSiO_2$ + Water	Liquid	38° to 60° Be Various ratios of Na_2O to SiO_2	Drums Tank Trucks Tank Cars	Mud conditioning.
Sodium Sulfate, Anhyd. Na_2SO_4	White Granules	99.8% Na_2SO_4	Bags Bulk Carloads	Detergents.
Disodium Phosphate, Anhyd. Na_2HPO_4	Powder Flake	48% P_2O_5	Paper Bags Fibre Drums	Detergents and mud conditioning.
Trisodium Phosphate $Na_3PO_4 \cdot 12H_2O$ *(TSP)*	Crystal	18.4% P_2O_5	Paper Bags Fibre Drums	Detergents and mud conditioning.
Tetrasodium Pyrophosphate, Anhyd. $Na_4P_2O_7$ *(TSPP) (Pyro)*	White Granules	52.1% P_2O_5	Paper Bags Fibre Drums	Detergents and mud conditioning.
Sodium Tripolyphosphate $Na_5P_3O_{10}$ *(Tripoly)*	White Granules	56% P_2O_5	Paper Bags Fibre Drums	Detergents and mud conditioning.

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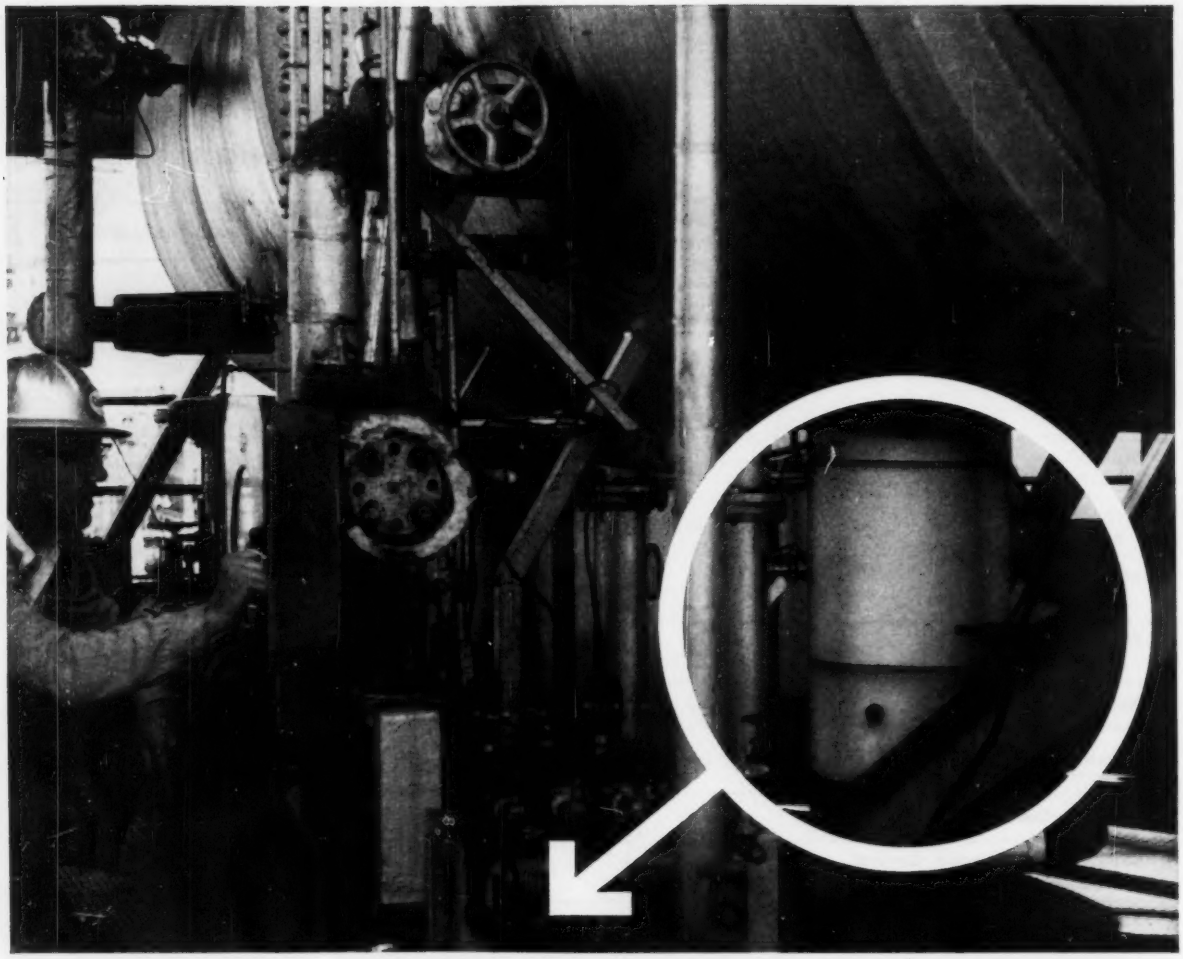

NO PROBLEMS NOW—This surge drum at Carter Division, Humble Oil & Refining Co., Billings, Mont., handles cracked gasoline vapors and sour water. Monel alloy linings for draw-off pot and outlet nozzle are giving good, reliable service on a job where material previously used was subject to extensive general sulfide attack and pitting.

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From refinery to refinery, of course, there is bound to be wide variation in the severity of sour waters. The Humble unit pictured above is employed in moderately corrosive service with a Wyoming crude. Their sour water contains 1% sodium and potassium sulfide at 100°F. Operators everywhere, however, generally agree that corrosion-resisting Monel alloy helps them avoid excessive downtime and out-of-line maintenance expense.

If *your* operations include the handling of sulfur-containing water, you should certainly investigate the advantages of using Monel alloy. Get all the facts in Technical Bulletin T-5, ***Engineering Properties of Monel.*** It's yours for the asking. And so is any help you may need in solving a materials problem. Simply write us.

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How to Do It...

What's the Best Choice Between Two Plant Expenses?

Dividing the initial cost by the expected life is not the answer

In the petrochemical industry, or in any industry, the proper evaluation of plant costs must include the rental rate on *money*. A high rental rate is, in effect, placed by the industry on its own money to control costs. Therefore, in comparing two alternative plant costs, the simple value of *initial* cost divided by years of service life *must not* be used in making the choice. It could be considerably higher than an alternative cost which is of cheaper over-all value.

In this article, the *total value* of a plant expenditure (initial cost plus rental) is related to years of service life. The correct choice of an expenditure from a number of possible expenditures can be made by referring to this relationship.

The initial cost of a piece of equipment is really a payment in advance for the service which the equipment will provide throughout its life. It is assumed that this initial cost is repaid at a constant rate throughout the life of the piece of equipment.

The value of total cost (initial cost plus rental) divided by years of life, to provide a piece of equipment can be expressed thus:

$$\text{Total cost per year} = \frac{X + iXp}{p}$$

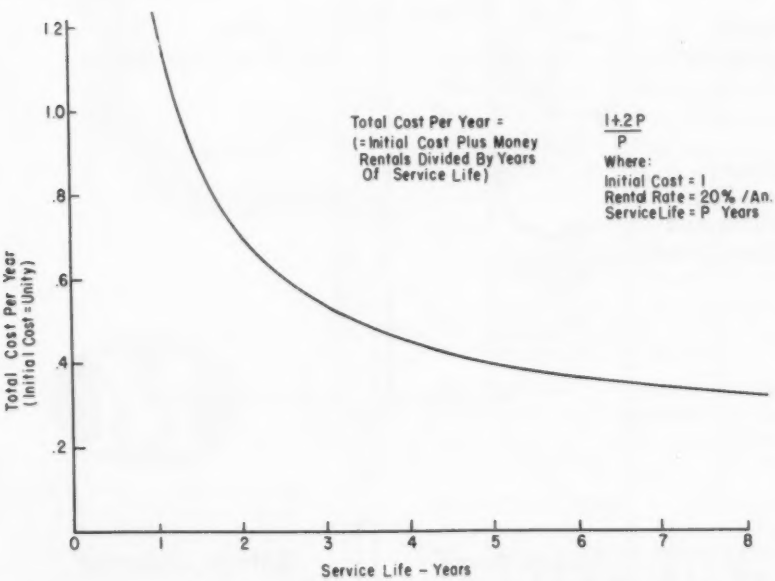
where X = initial cost
i = rental rate per annum
p = expected life

A money rental rate of 20 percent per annum on the total initial cost is commonly used when considering a plant replacement. Using this figure, and taking the value of the initial expenditure to be unity, the above equation becomes:

$$\text{Total cost per year} = \frac{1 + .2p}{p}$$

From this equation, the value of total cost per year of life is plotted against length of service life in Figure 1.

Since the initial cost of an item is unity in Figure 1, the total yearly cost in dollars can be found by multiplying the initial cost by the ordinate value for the expected life. A true comparison between alternate expenditures can therefore be determined.



Expenditure (initial cost plus rental) per year of service life plotted against years of life, initial cost = 1, for an expenditure on plant equipment.

Example: It is required to decide on the best course of action in the case of a heat exchanger whose tube bundle is gone. It is possible to provide either:

A.—A completely new replacement bundle installed at an estimated cost of $6,800, and having an expected life of six years, or,

B.—A re-tube job using the same tube sheets, estimated at $5,000 total cost, and having an expected life of 3½ years.

At first sight, the yearly costs of these alternatives could be taken mistakenly as initial cost divided by years of life. Thus A would appear to be the better choice at $1,133 per year, as against B at $1,430 per year. In actual fact the total yearly costs, rental included, for six-year life and for a 3½-year life are .37 and .49 (ordinates in Figure 1) times initial costs. Or, the total yearly cost for

A is 6800 x .37 = $2,520, and
for B 5000 x .49 = $2,450.
Therefore B is the better choice.

Item submitted by J. S. Maloney, Sarnia, Ontario, Canada.

Strahman

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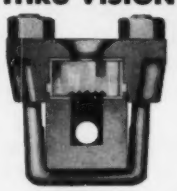

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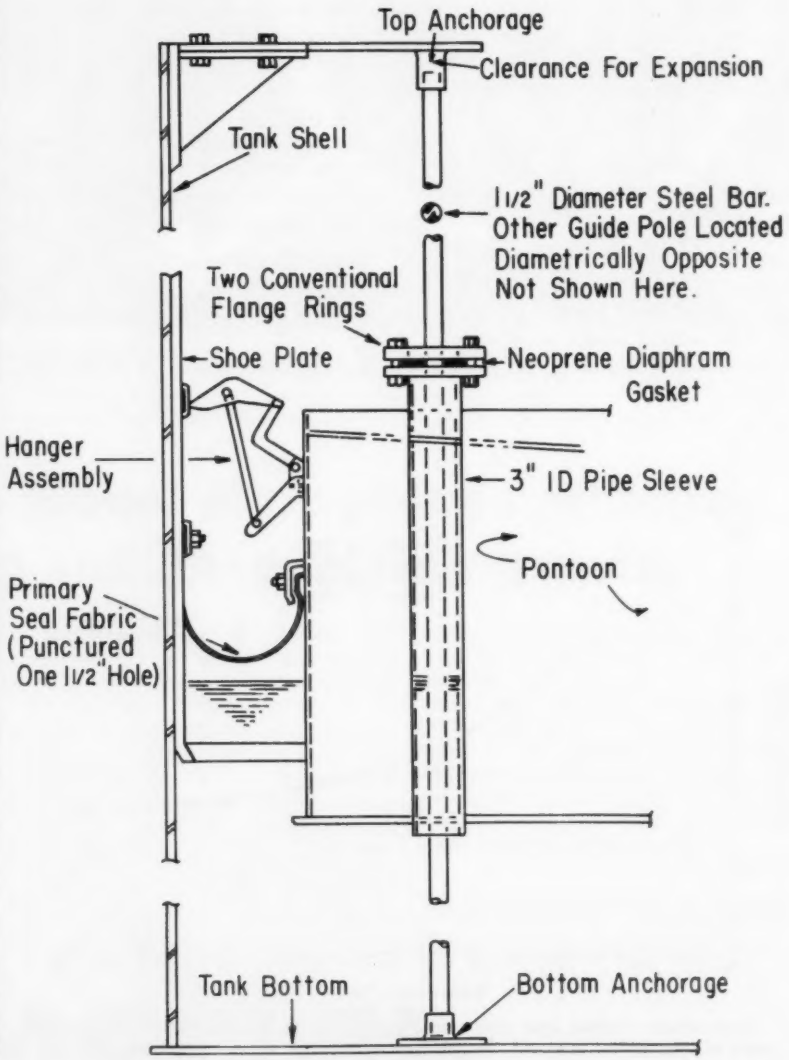
On August 15, 1959, Kaohsiung City, (Formosa) was rocked by an earthquake which lasted 30 minutes. It was classified as grade three on the Richter scale of earthquake magnitude.

At our marine terminal, two 80,000-barrel floating roof tanks were under construction. One is a double-deck type, which was undergoing a water test. It was being filled with water at the rate of 150 cubic meters per hour, and the roof rose at the speed of 0.47 feet per hour correspondently. At the moment of quake, the roof was about 29 feet above the tank bottom.

After the earthquake, a careful joint inspection of the tank being tested was made. It was found that the guide way on the shoe plate had jumped off the guide rail and had traveled 8 inches in a clockwise direction. A clean splash mark 9½ inches high was left on the shell which indicated a movement caused by rolling and pitching of the pontoon during the quake. Eighteen sets of hanger assemblies were badly distorted. One hanger bolt even stretched and broke. The primary seal fabric was punctured. A 1½-inch hole was in the bottom of the seal sag located diametrically opposite the guide rail. The pontoon was rotated 3½ inches relative to the shoe plate in a clockwise direction.

We concluded that the pontoon roof was given two principal motions



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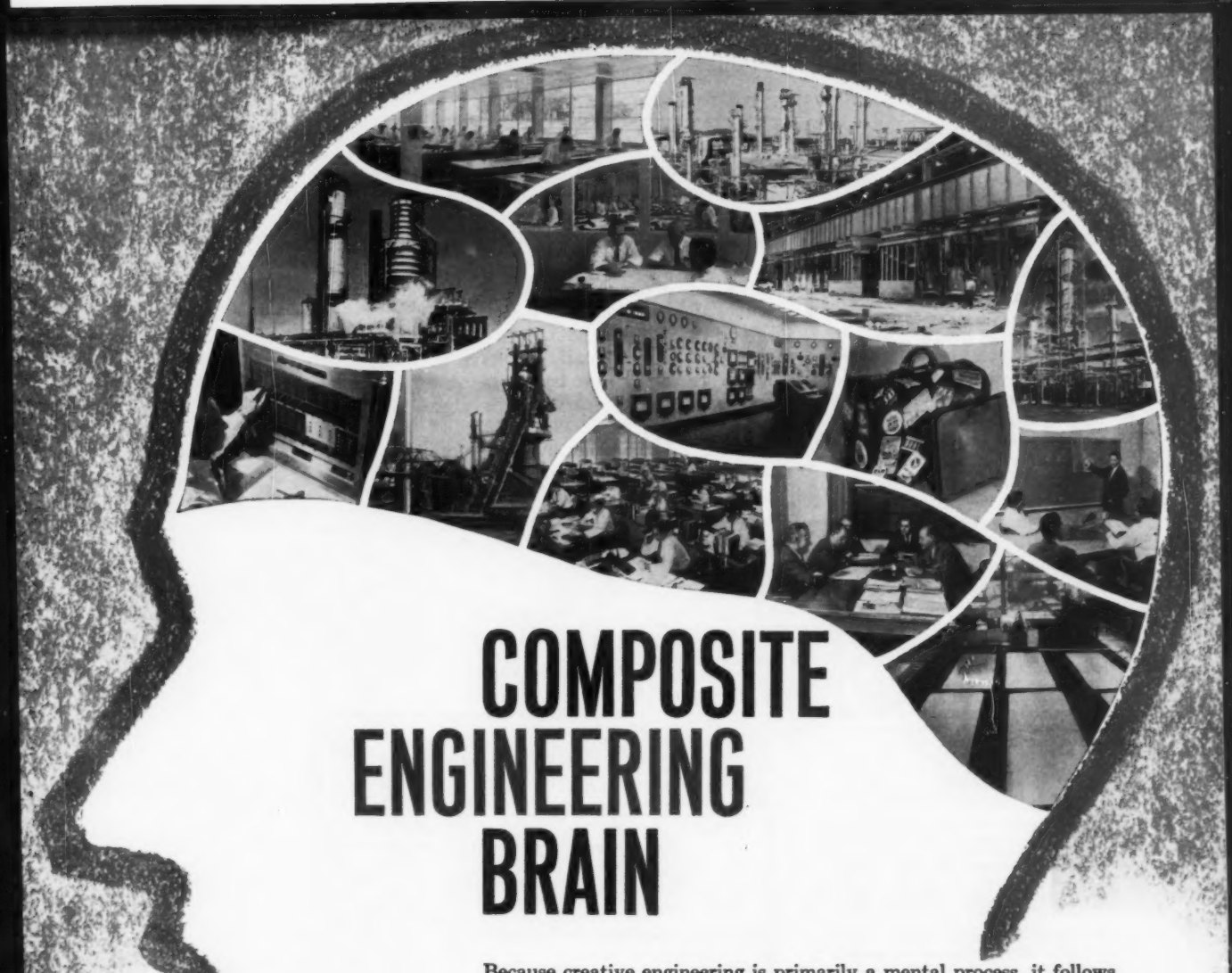

COMPOSITE ENGINEERING BRAIN

Because creative engineering is primarily a mental process, it follows logically that the best engineering is produced by the best-qualified brains.

Since its founding in 1905, Arthur G. McKee & Company have always been successful in seeking out and attracting to this organization, not the merely adequate or the competent, but those outstanding men in their fields who have superior engineering ability, training and experience.

Today McKee and its subsidiaries can offer you the services of a permanent staff of some 1700, not including field construction personnel. Among them are internationally-recognized authorities in the design and construction of facilities for the production of iron and steel, the processing of petroleum, petrochemicals and chemicals, and for the treatment and handling of raw materials. Specialized groups are available on such projects as sintering and pelletizing plants, sulfuric and nitric acid plants, coke by-product plants, non-ferrous metal facilities and similar projects.

The combined knowledge of these men form, in effect, a composite engineering brain capable of undertaking projects of any size, in any location, for the industries we serve—a brain that could be invaluable to your company on your next project.

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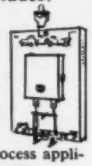
McKEE ENGINEERING
AND CONSTRUCTION SERVICES

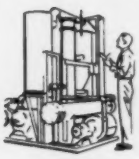
WILLIAM C. DIMAN, Atmosphere Equipment Specialist, reports . . .

MODERN PROCESSES DEMAND MODERN ATMOSPHERES

Ever since 1927, when C. I. Hayes perfected the first controlled-atmosphere heat treating furnace, we have made a steady effort to further the technology of atmosphere generators and dryers. By recommending proper generators and dryers, we have helped our customers speed production, improve product uniformity and quality and save processing time and trouble. The big Hayes equipment line includes:



MOLECU-DRYER (using LINDE'S Molecular Sieves) — for drying, sweetening, purifying protective atmospheres and for gas and liquid separation and recovery. Exit gas dew points to less than minus 100°F. Many standard sizes available for process applications, instrument air drying, etc.



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NITROGEN GENERATORS (using LINDE'S Molecular Sieves) — produces 99.99% pure inert gas at about 20¢ per 1000 cu. ft. Standard sizes from 1000 CFH to 10,000 CFH.

"ENGINEERED ATMOSPHERES" — HAYES offers a broad range of equipment for producing oxidizing, reducing, carbon-potential, and nitrogen-hydrogen atmospheres . . . also engineered equipment packages for stand-by (start-ups, emergencies, etc.). Standard sizes are available in all types Exothermic, Endothermic, and forming gas generators — also ammonia dissociators.

Hayes offers more than just equipment. Our Engineering organization and experimental lab. are ready to help make sure you get the right atmosphere equipment for your work.

ASK FOR BULLETINS . . .	Bulletin No.
Molecu-Dryer	5703-A
Nitrogen Generator	5901-NI
Exothermic Generator	256-A
Endothermic Generator	5808-A
Ammonia Dissociator	5810-D
General Bulletin	5810-GC
Forming Gas Generator	256-A

C. I. HAYES, INC.

Established 1905

853 WELLINGTON AVE., CRANSTON 10, R. I.

ELECTRIC FURNACES

It pays to see Hayes for metallurgical guidance, lab facilities, furnaces, atmos. generators, gas/liquid dryers.

How to Do It . . .

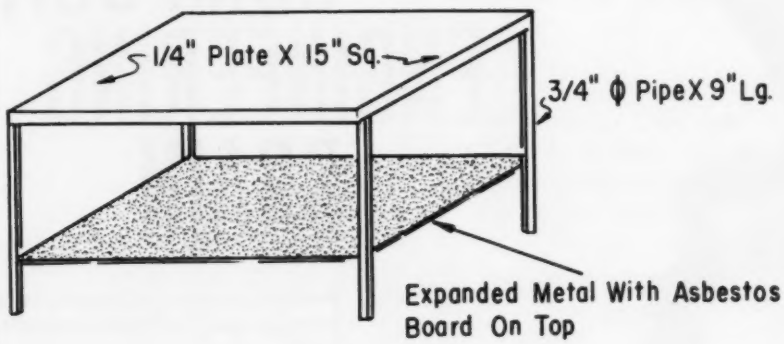
during the earthquake; i.e., rotation as well as rolling and pitching. The tank is designed so that the shoe plate is fixed against rotation and is connected to the pontoon roof by 32 sets of linkage which permit a free rotation within designed limit. During the quake, the pontoon roof moved far beyond its allowable limit so that the shoe plate was derailed and the hanger assemblies were badly twisted.

On the island, earthquakes are rather frequent. Since 1945, Formosa has been hit five times by grade six earthquakes. From the standpoint of safety, a study was made of a practical way to stabilize the floating roof and make a suitable anti-rotating device for a pontoon-type roof.

Our remedy was to install two guide poles on the floating roof tank. The poles were located opposite each other and about 8 inches inside the pontoon rim. The pole was made from a 1½-inch diameter solid steel bar the length of which was the tank height. A 3-inch pipe sleeve was attached to the pontoon where the guide pole passes through inside (See Figure). The sleeve opening above the deck was sealed with a neoprene diaphragm gasket tightened against the guide pole, shown in illustration.

In earthquake areas, we feel that the two-guide-pole system will more effectively protect the pontoon roof from rotation as well as rolling and pitching. Another advantage is that the pontoon can so be guided into position easier and steadier.

Item submitted by Tzen-Yung Yang, Chinese Petroleum Corp., Kaohsiung, Taiwan (Formosa).



Cheap Hot Plate Keeps Cooks Off Lab Equipment

A 15-inch square of ¼-inch steel plate makes an excellent laboratory hot plate when heated by a domestic gas ring (or burner). If refinery gas is used for heating, the operating cost becomes virtually zero.

A simple and effective hot plate can be made easily and cheaply in any fitting shop by welding four 9-inch legs on the corners. These pipe legs are stayed by tackwelding a platform of expanded metal flooring 2 to 3 inches above the bench level. A thin sheet of asbestos board on this platform supports the gas ring and prevents the heat radiated from the steel plate from damaging the bench-top.

Experience has shown that it is advisable either to supply a special "staff" hotplate or issue an injunction against the grilling of lunchtime steaks on laboratory equipment!

Item submitted by George E. Mapstone, Johannesburg, South Africa.

How Much Liquid in a Vessel If Only Depth Is Known

If you have a 10,000-gallon horizontal, cylindrical vessel, 9 feet in diameter with ASME dished heads, how many gallons of liquid are in the vessel if the liquid level is 3 feet above the bottom?

Use the table and you can find the answer for any diameter vessel. Here's how its works:

First, you divide the liquid level multiplied by 100 by the vessel diameter to find percent level. In the ex-

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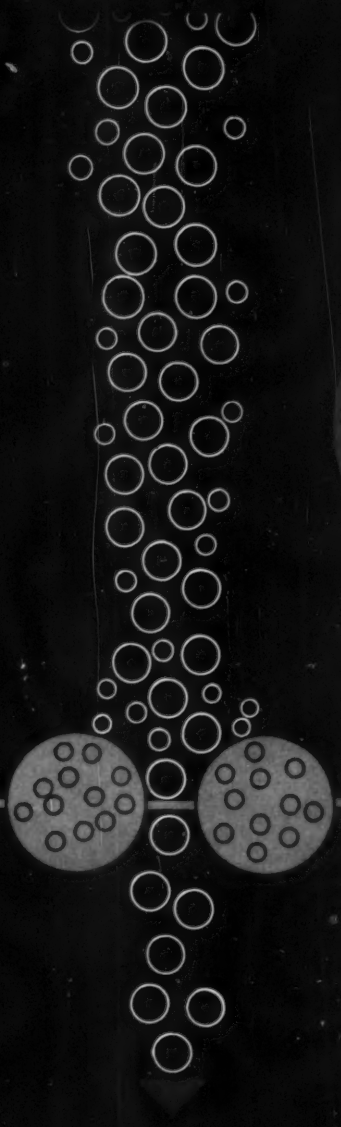

NOW—DRY NATURAL GAS MORE ECONOMICALLY

...WHEN YOU ADSORB WITH LINDE MOLECULAR SIEVES

This is only one of many applications which utilize the high capacity and selectivity of LINDE Molecular Sieves. In fact, Molecular Sieves not only outperform other adsorbents, but do other adsorption jobs never before accomplished. Whether in new installations or as replacement adsorbent in existing units, Molecular Sieves can help you minimize both investment and operating costs. More specifically, here's how they are used. . . .

A major petrochemical company has reduced the CO_2 content of its ethylene from 3000 PPM to less than 1PPM. This high purity is achieved in a single-stage process, automatic and non-corrosive, which has proved to be more economical than the alternative four-stage process. Other petrochemical uses include drying of cracked gases, ethylene, hydrogen, liquid propylene, solvents and many other gases and liquids. **Natural gas producers** use Molecular Sieves for drying and sweetening of natural gas, for sweetening of liquid propane and butane, and for drying of adsorber oil. **Petroleum refiners** use them to gain efficiency in drying reformer hydrogen, liquid butane LPG and transformer oil, and for removal of impurities such as CO_2 and mercaptans **Refrigeration manufacturers** use Molecular Sieves as a desiccant in super-drying refrigerants to eliminate freeze-up and corrosion.

For these and many other adsorbent applications, you can rely on patented LINDE Molecular Sieves to perform more effectively. They are the top quality material of their kind available today, always uniform, with high capacity, high strength, and high bulk density. They are available in regular and special grades to meet your specifications.

LINDE technical know-how—gained from years of laboratory and field work with adsorption problems—can help make Molecular Sieves work profitably for you. For further information, write: Dept. **PR-11** Linde Company, Division of Union Carbide Corporation, 270 Park Avenue, New York 17, N. Y. **In Canada:** Linde Company, Division of Union Carbide Canada Limited, Toronto 7, Canada.

SOME AREAS WHERE MOLECULAR SIEVES IMPROVE ADSORPTION

- Purification of ethylene
- Drying gases, liquids, solvents
- Drying, sweetening natural gas
- Sweetening liquid propane, butane
- Drying jet fuels
- Octane improvement
- As refrigerant desiccant
- Controlled atmosphere purification

LINDE COMPANY

UNION CARBIDE

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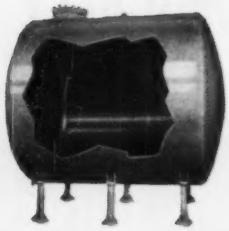
No added cost to you!

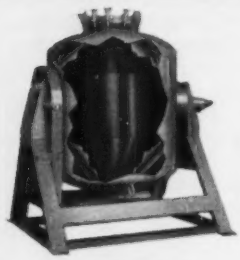
"Special" 778 glass now standard



STORAGE TANKS

HEAT EXCHANGER TUBES

COLUMNS



DRYER-BLENDERS

REACTORS

For more data on advertised products, use Readers' Service Cards, last page.

on all Glascote® process equipment

When we introduced Glascote 778 glass we knew many processors would want it — but we didn't expect a **landslide!** Today so many of our customers specify this remarkably acid-resistant glass that we've made it **standard** on all Glascote reactors, columns, storage tanks, rotary dryer-blenders, pipe and fittings.

This means that, at no extra cost, you will get a unique glass lining that extends acid resistance up to 75°F higher operating temperature **with no sacrifice in its ability to resist alkali and thermal shock!**

For your convenience we have prepared a "resistance rule" (pictured at left). It lists 150 hard-to-handle substances from acetaldehyde to zinc sulfate, and shows at a glance the ability of Glascote 778 to resist their corrosive attacks.

Nevertheless, despite the overwhelming popularity of 778 glass lining, you should keep in mind that this is just one of 3,000 formulations. Some may be even better for your special requirements. Ask the Glascote representative who calls on you.

Through research ... a better way

A.O.Smith
CORPORATION

Subsidiary: GLASCOTE PRODUCTS, INC.
CLEVELAND 17, OHIO
World's largest manufacturer of glass-protected steel products

Please send me a handy "resistance rule" for use with Glascote 778 glass.

GLASCOTE PRODUCTS, INC.
20900 St. Claire Ave., Cleveland 17, Ohio

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Now... measure

SOLUTION CONDUCTIVITY

continuously

with this new L&N Conductivity Monitor

Unusually compact, this Conductivity Monitor is completely transistorized. Its advanced circuitry assures reliable, maintenance-free performance. It is unmatched in providing direct-reading measurements in the laboratory or on the process line.

Other outstanding features include:

- a wide choice of ranges, for versatility of application.
- continuous alarm signalling, if desired.
- an output d-c signal for transmission to a recorder or other data logging equipment.
- a model to meet *your* needs: either a panel- or wall-mounted industrial model (as illustrated), or a lightweight portable model with handle for easy carrying.

Prices start at $195 for the Industrial Model. The price is $225 for the Portable Model.

Ask for Data Sheet E-95(3) from Leeds & Northrup Company, 492 Stenton Ave., Philadelphia 44, Pa., or your nearby L&N Office.

LEEDS NORTHRUP
Instruments Automatic Controls • Furnaces

How to Do It . . .

Table: Percent level vs. content of horizontal vessels with ASME dished heads.

Percent Level	Percent Content	Percent Level	Percent Content	Percent Level	Percent Content	Percent Level	Percent Content
0	0.0000	26	0.2070	51	0.5128	76	0.8150
1	0.0043	27	0.2183	52	0.5255	77	0.8258
2	0.0070	28	0.2295	53	0.5382	78	0.8364
3	0.0108	29	0.2409	54	0.5509	79	0.8468
4	0.0153	30	0.2526	55	0.5635	80	0.8570
5	0.0207	31	0.2643	56	0.5762	81	0.8671
6	0.0261	32	0.2761	57	0.5888	82	0.8769
7	0.0323	33	0.2880	58	0.6014	83	0.8865
8	0.0389	34	0.3000	59	0.6136	84	0.8959
9	0.0459	35	0.3121	60	0.6264	85	0.9051
10	0.0533	36	0.3242	61	0.6382	86	0.9140
11	0.0610	37	0.3365	62	0.6574	87	0.9226
12	0.0690	38	0.3486	63	0.6635	88	0.9310
13	0.0774	39	0.3618	64	0.6758	89	0.9390
14	0.0860	40	0.3736	65	0.6879	90	0.9467
15	0.0949	41	0.3864	66	0.7000	91	0.9541
16	0.1041	42	0.3986	67	0.7120	92	0.9611
17	0.1135	43	0.4112	68	0.7239	93	0.9709
18	0.1231	44	0.4238	69	0.7357	94	0.9768
19	0.1329	45	0.4365	70	0.7474	95	0.9793
20	0.1430	46	0.4491	71	0.7591	96	0.9847
21	0.1532	47	0.4618	72	0.7705	97	0.9892
22	0.1636	48	0.4745	73	0.7817	98	0.9930
23	0.1742	49	0.4872	74	0.7930	99	0.9957
24	0.1850	50	0.5000	75	0.8041	100	1.0000
25	0.1959	..	.....	..	.....	..	.....

ample above, 3 x 100 divided by nine equals 33 percent.

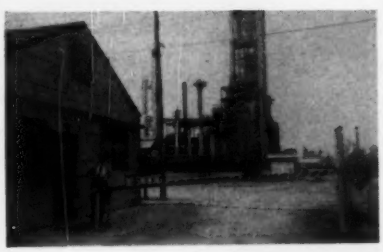
Second, enter the table at the percent level and find the constant. Multiply this constant by the vessel capacity and you will have the volume required. In the example, the constant for 33 percent is 0.2880.

Therefore, the content of the vessel when there is three feet of liquid in the bottom is .2880 x 10,000 equals 2,880 gallons.

Idea submitted by Remy Van Haelst, Antwerp, Belgium.

Yank on Sash Cord Opens Plant Gate

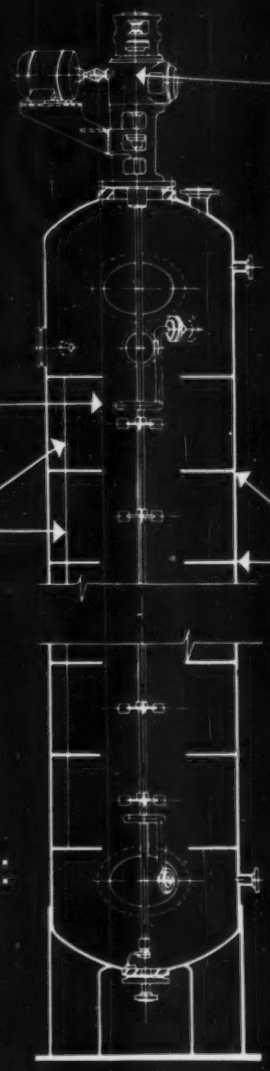
Lester Black, guard at the Delhi-Taylor Refining Corp.'s plant at Corpus Christi, Texas, demonstrates how he allows the traffic to pass without moving from his desk. A sash



cord runs around a wheel section that looks like a bicycle rim and connects to the top of the gate. The gate is perfectly counterbalanced so that a slight pull will raise it. By using this device, he can actually hold down two jobs at once as he does not have to leave the telephone to raise the gate.

YOUR IDEAS ARE VALUABLE!

At least $10 will be paid for each idea accepted for "How to Do It." Just send a brief note with a photo or sketch to the Editor, *Petroleum Refiner*, P. O. Box 2608, Houston.



DRIVE of time-proved LIGHTNIN Mixer design.

MIXING controls the retention time in baffled stages; holds solids in suspension as required.

BAFFLES set up controlled-regime flow pattern, making possible accurate scale-up and predictable results.

STAGE PROPORTIONS and separators are designed for each specific application.

Versatile new process tool:

LIGHTNIN CMCONTACTOR®

Now...handle any fluid system by the continuous route

Anything that's fluid — including heavy slurries and thick viscous liquids — will go through this continuous multistage contactor.

Inside the column, controlled mixing takes hold. It creates uniformity, if that's what you're looking for. It hones the efficiency of a liquid-liquid extraction. Or it hikes the mass-transfer rate in a gas-liquid system. Or holds a solid catalyst imprisoned uniformly in suspension, through all stages.

We build the LIGHTNIN CMCONTACTOR to fit your process. Column diameter, stage height and number, impeller speed and diameter, and stage opening size are just a few of the variables which MIXCO takes into consideration in designing your column. We build it in materials of your choosing.

Best of all, you *know* what it's going to do for you, long before the equipment goes up in your plant. There's no guesswork at all. From test runs, we can tell you what your results will be in the final unit. And we guarantee them to be that way.

If you prefer, you can buy or rent a pilot-plant CMCONTACTOR and we'll help you make your own test runs.

If you'd like to know more about this new idea in continuous processing, call in your LIGHTNIN Mixer representative. He's listed in Chemical Engineering Catalog and in the yellow pages of your telephone book. Or write us direct.

CMContactor can be as small as six inches or as large and as high as needed. Corrosion-resistant materials are readily supplied.

Lightnin® Mixers

MIXCO fluid mixing specialists

MIXING EQUIPMENT Co., Inc., 164-m Mt. Read Blvd., Rochester 3, N.Y.

In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Ave., Toronto 19, Ont.

3 Reasons Why

Robbins VALVES Are the Most Economical You Can Buy

1. The only valves that can be completely serviced in less than 1 minute from the front of mounting panel without removing the valve from the line!

To service a Robbins Metering & Shut-Off Valve it is only necessary to remove the handle, loosen locknut and remove barrel assembly . . . all accomplished from the front of the panel . . . no need to disturb the line connections!

2. Single barrel assembly!

For both civilian and military installations the single barrel assembly design and construction features (barrel, spindle, spindle seals, barrel seals and seat in one unit, cleaned, lubricated, sealed for oxygen service) mean practically instantaneous renewal of service without disconnecting any plumbing.

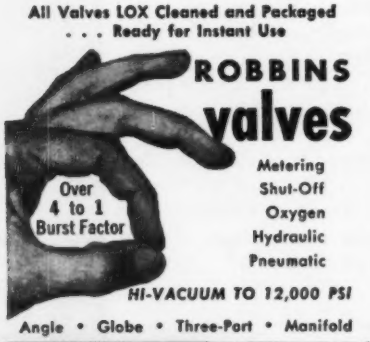
3. As many as 5000 cycles before requiring servicing!

Many Robbins Metering Valves . . . in constant use on an 8-hour a day basis for three years . . . have never required servicing, lubrication, or any parts replaced!

...And the Most Reliable!

Precision made and tested. Design capabilities, manufacturing procedures, and quality control operations at Robbins Aviation are all directed toward one objective . . . to produce a valve of the highest quality that will provide the user with the greatest reliability and the greatest economy over many years of service.

All Valves LOX Cleaned and Packaged . . . Ready for Instant Use



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New Books...

Advances in Refining

"Advances in Petroleum Chemistry and Refining, Volume III" takes the fundamental knowledge of chemistry and chemical engineering and transforms it from a simple processing industry for fuels and lubricants to an extremely complex chemical process industry which has branched out into synthetic rubber, plastics, fertilizers, and many other fields.

Continuing the classifications of the previous two volumes, the chapters are subdivided into five groups: (1) Economics and Future Trends, (2) Unit Operations and Design, (3) Refining Processes, (4) Petrochemicals and (5) Mechanical Equipment. Included under these general categories are such specific chapters as: Economics of Petrochemicals, Liquid Thermal Diffusion, Fired Tube Heaters, Mechanism of Hydrocarbon Isomerization, Hydrogenation of Petroleum and Its Fractions, Hydrofluoric Acid Alkylation of Paraffins, Hydrocarbon Oxidation, Manufacture of Petrochemical Acetylene, Chemistry of the Sulfur Compounds in Petroleum and Recent Advances in Cooling Towers.

Although the material satisfies the requirements of comprehensive review articles, emphasis on the practical side makes the work of day-to-day value. Volume I was reviewed in PETROLEUM REFINER, August 1958, and Volume II in PETROLEUM REFINER, July 1959.

(Kobe, Kenneth A., McKetta, John J., *Advances in Petroleum Chemistry and Refining, Volume III,* Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N.Y., 544 pages, $16.80. For sale by Gulf Publishing Co., P. O. Box 2608, Houston 1, Texas.)

Great Organizers

"The Great Organizers" is a new insight into high-level management of business, through profiles of managerial geniuses who solved organizational problems of DuPont, General Motors, Westinghouse, and National Steel. It describes methods used, compares management theories, points out fallacies, and presents practical material on understanding corporate organization.

The book uses actual case histories to develop criteria of action applicable to corporations with comparable problems and conditions. It gives profiles of the "great organizers"—the executives who transformed DuPont from a "one-man" organization on the verge of being sold, to one that utilizes the skills and knowledge of many; those who saved General Motors from potential bankruptcy, and laid the foundation for its present success, and those who successfully decentralized Westinghouse. Results of this decentralization are discussed, as well as the immediate, short-term, and long-term effects on expenses and profits that can be expected by a company contemplating similar action. Also described is the work of the founder of National Steel, whose organizational plans were so advanced that no reorganization was necessary for several decades.

(Dale, Ernest, *The Great Organizers,* McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, N.Y., 277 pages, $5.95. For sale by Gulf Publishing Co., P. O. Box 2608, Houston 1, Texas.)

Air Pollution Control

"Symposium on Air Pollution Control" centers on the influence of wind and weather on air pollution potential of industrial areas as an important factor in plant location and in measures needed to reduce air pollution. In addition to meteorological consideration, the symposium includes papers on analytical methods for aldehydes and fluorides in the atmosphere. The latter discussion is concerned with the rather difficult but very important separation of gaseous and particulate fluorides.

This symposium was sponsored by ASTM Committee D-22 on Methods of Atmospheric Sampling and Analysis. The volume contains numerous references.

(*Symposium on Air Pollution Control,* American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., 44 pages, $1.50.)

Handbook of Chemistry

"Handbook of Chemistry and Physics," up-dated for the 42nd time, is the only one-source reference in the world covering mathematics, physics and chemistry in one volume. Used internationally in research, engineering, education and business, it is continuously revised and annually published.

Over 200 prominent collaborators, who are recognized authorities in their own science research fields, have contributed to make up the data, classified under five handy indexes. New tables include: Diffusion of Metals into Metals, Interplanetary Orbits, Standard Types of Stainless Steel, to mention a few. Among the revised, expanded and up-dated data are: Atomic Weights, Trade Names of Plastics, Nuclear Spins, and many others.

(*Handbook of Chemistry and Physics,* Chemical Rubber Publishing Co., 2310 Superior Ave., Cleveland 14, Ohio, 3400 pages, $12.)

Heart Disease

"Heart Disease, Blood Pressure and Strokes" is an authoritative book with a light touch. Written about the nation's number one killer, heart disease, the work has been compiled especially for people who know nothing about medicine but are concerned about their own health.

Dr. C. A. D'Alonzo, assistant director of DuPont Co.'s Medical Division, has drawn on the company's preventive medical program for employes and the research of the medical profession to throw some understanding light on a worrisome

DU PONT *Petroleum Chemicals* NEWS

Number 105 in a series of bulletins for the Petroleum Industry

NOVEMBER • DECEMBER 1960

NEW CINEMASCOPE MOVIE

gives America the BIG picture on travel

There you are – in your favorite theater . . . or your neighborhood "drive-in" – and suddenly you're driving across the Painted Desert, in the vibrant glow of early morning. Colors flash by. Music swells around you. Your spirit of adventure runs high.

The scene changes, and you're passing through a forest of giant sequoia trees. Then cruising down the beach at Daytona. And seconds later you're pulling into an historic 100-year-old village in New England.

The music rises, and a title sweeps across the wide Cinemascope screen: "Down the Road."

55 Million Viewers

For the next 9½ minutes, you will tour America. You and millions of other Americans – some 55 million of them.

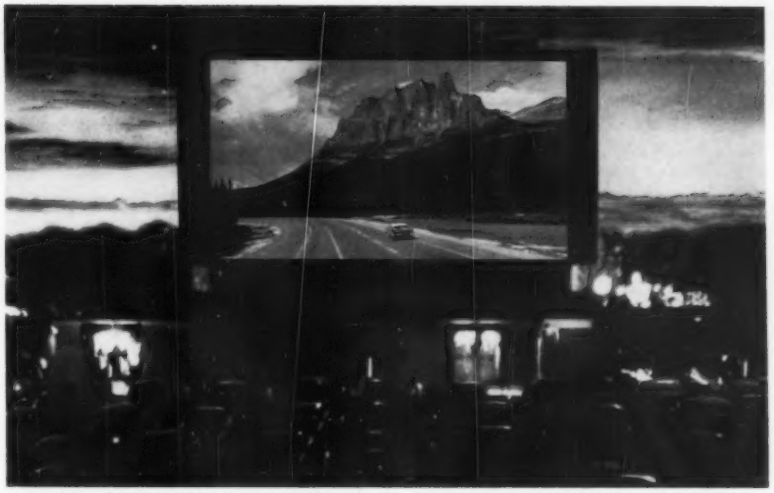
You'll swing across the continent from Atlantic to Pacific, Alaska to Mexico. You'll look, watch, drive, fish, swim, photograph, poke and probe your way across this great and various land.

"Down the Road" is a color Cinemascope movie. Sponsored by DuPont, it will be distributed on an international basis by 20th Century-Fox, starting with theaters all across America in December. This distribution will provide the oil industry with a *broad* "expand the demand" promotion. As such, it affords *your* company a natural backdrop to your own travel development activities.

Encourages Travel

In production for a full year and shot entirely on location – "Down the Road" will encourage a greater appreciation of the heritage and beauties of America, and stimulate public interest in seeing them firsthand through the convenience and comfort of the family car.

The movie is a fast-moving panorama that sweeps all the way from snow-capped peaks along the Alaskan Highway to sun-capped skyscrapers in Manhattan, from popular vacation



spots like the Grand Canyon to out-of-the-way lakeside camp sites, from the excitement of a Mardi Gras to the thrill of a county fair.

"America is a land as close to home as the point of view, and as far away as a thousand horizons." This narrative in the film points out that today's highways make *all* America our playland – to see, to admire, to cherish. But there's more than just scenery in this film. Woven into it are strong messages on safe driving, and for keeping the trip completely enjoyable with the help of America's network of service stations.

From start to finish, "Down the Road" is an entertainment motion picture, created to capture the imagination of theater audiences. Its single purpose is to appeal to the sense of adventure and pride we all share in America – and the ease with which our cars can bring it to life. It is expected to be one of the motion picture highlights of the coming year.

"Down the Road" will appeal to *all* motorists. Watch for it in *your* marketing area, starting in December.

Why Du Pont Sponsored "ROAD"

W. A. TAFT, Director of Sales of the DuPont Petroleum Chemicals Division, explains the purpose behind DuPont's sponsorship of the film "Down the Road."

"As partners in the oil industry, DuPont has always sought unique, fresh approaches to the building and expansion of markets for petroleum products.

CONTINUED OTHER SIDE

ADVERTISEMENT—Prepared for the Petroleum Chemicals Division of E. I. du Pont de Nemours & Company (Inc.)

OVER

DU PONT *Petroleum Chemicals* NEWS

CONTINUED

Why Du Pont Sponsored "ROAD"

W. A. TAFT, Director of Sales, Du Pont Petroleum Chemicals Division

"With the vast improvement in our highway system and in tourist accommodations, the time has arrived when motorists can readily and easily come to appreciate the many scenic values America has to offer. There is much to see. Adventure awaits us in all directions. All the average family needs is a little push, a little encouragement, to get them out of their own neighborhood and on the roads of America. This film is intended as a sampling of what awaits them beyond their own surroundings – to whet their appetites and give them that push.

"Naturally, a promotion of this type offers several advantages to the oil industry at large. When people take longer trips, they need more gasoline, oil, lubricants and allied products. They also get the travel habit, once the ice is broken. And finally, we're convinced that people who make planned automobile 'tours' are more inclined to take impromptu trips on week-ends and holidays. It all adds up to better business."

Du Pont TETRAMIX* combines the best of TEL and TML

Tests at our petroleum laboratory have shown that, in many cases, desired road octane levels can be achieved more economically with Du Pont's new lead antiknock, TETRAMIX, than with other lead compounds.

This new additive contains a combination of all possible methyl-ethyl lead compounds, including small amounts of TEL and TML. The result is a blending of the benefits of tetraethyl and tetramethyl lead into a single additive that offers you refining flexibility as well as lower lead costs for a given road octane level.

While the effectiveness of TETRAMIX varies with gasoline composition (as is true with TEL), it is effective in low, medium or high concentrations. It is also more effective in many gasolines on a cost-per-gallon basis than either TEL or TML.

Get in touch with your Du Pont Petroleum Chemicals representative. Because we offer all three compounds – TEL, TML and TETRAMIX – he can offer impartial advice in selecting the one additive best suited to your gasoline stocks.

*Trademark

PHILADELPHIA DISTRICT MANAGER

CARL W. FERRIS became manager of the Du Pont Petroleum Chemicals Division's Philadelphia District in July of 1959.

Mr. Ferris has exceptional experience and qualifications for helping refineries in his district, in the use of TEL, TML, Du Pont TETRAMIX antiknock compound and other additives.

He joined the Du Pont Company in 1947, and his first assignment was at the Du Pont Petroleum Laboratory, where he worked on fuel blending studies in the single cylinder engine laboratory. He then did road test work with the Du Pont fleet of fuel test cars. He was transferred to the Division's central region in 1951, where he served, successively, as regional automotive service representative, sales promotion coordinator, an account manager, and manager of the Chicago District.

Prior to his present position, he was on special technical and planning assignments in Wilmington.

A graduate of Cornell University, Mr. Ferris has a Bachelor of Mechanical Engineering degree. During World War II, he served nearly three years in the U. S. Navy and held a commission as Lieutenant, jg. He is a member of the Society of Automotive Engineers.

His main interests outside the office are gardening and woodworking. Carl is married and the father of two young girls.

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Better Things for Better Living
...through Chemistry

Du Pont Lead Antiknock Compounds and other Petroleum Additives

OVER

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Printed in U.S.A.

Books . . .

problem. His light touch approach removes many of the fantasies that can actually worry some people sick and simultaneously points up the things about which they ought to worry and see their doctor. For while it is well known among doctors, it is probably not among the public that heart disease is not necessarily fatal and many things can be done about it.

The book stresses what heart diseases are, how they work, what they do to people, and the most likely things people can do to head them off.

(D'Alonzo, C. A., *Heart Disease, Blood Pressure and Strokes,* Gulf Publishing Co., P. O. Box 2608, Houston 1, Texas, 159 pages, $3.50.)

Standardization Directory

"Standardization Activities in the United States—A Descriptive Directory," provides a descriptive inventory of the work and objectives of organizations, both public and private, involved in standardization and activities. Each organization is listed alphabetically with a brief description of its standardization area and accomplishments.

A comprehensive index covers almost all widely known product areas, textiles, paper, leather, ceramics, plastics, electrical equipment, rubber, cement, etc., and lists the organizations in each field. Not only products are standardized, but also materials, methods, techniques, sizes, nomenclature, services, and other areas.

Standardization Activities in the United States—A Descriptive Directory, U.S. Government Printing Office, Washington 25, D.C., 210 pages, $1.75.)

Kinetics Tables Index

"Alphabetical Index to Tables of Chemical Kinetics, Homogeneous Reactions, National Bureau of Standards Circular 510, Supplement 2," provides a subject index, and both a class of reaction and class of compound alphabetical index. It also includes an explanation of the six digit numbering system that is used in the tables.

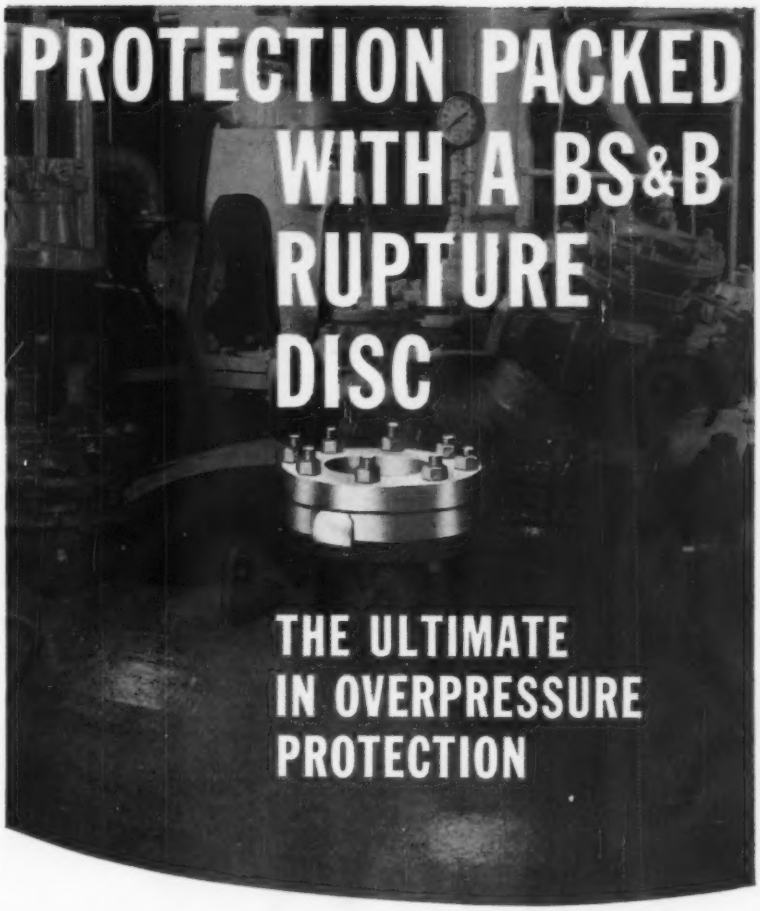
The emphasis is placed on experimentally ascertained facts, and data depending on interpretations are not generally included.

(*Alphabetical Index to Tables of Chemical Kinetics, Homogeneous Reactions, National Bureau of Standards Circular 510, Supplement 2,* U.S. Government Printing Office, Washington 25, D.C., 37 pages, 35¢.)

Human Enterprise

"The Human Side of Enterprise" deals with policies and practices in the management of human resources in business and industrial organization, examining them in the light of current social science knowledge about human nature and behavior. Two important suppositions form the basis of this material:

Theory X—The assumptions upon which traditional organizations are based



If you have a pressure system equipped with a relief valve you will want this added safety measure.

BS&B Rupture Discs act fast providing an unrestricted relief opening. Discs are available in sizes ranging from ⅛" to 44" in diameter, covering rupture pressures from 3 to 100,000 PSI.

Specially engineered discs (DV) provide relief under a wide range of operating conditions including high tolerances—high temperature — pulsating pressure or alternating pressure and vacuum situations.

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WE HAVE DESIGNS ON
EVERYBODY'S CHARGE STOCK

Serving processors who want high yields of high octane gasoline begins at Houdry, with three efficient and flexible catalytic processes.

The HOUDRIFLOW Process accepts in liquid or vapor form any fraction between naphtha and asphalt from both sweet and sour crudes. In the HOUDRESID Process, reduced crudes are converted into high octane gasoline and light distillate fuel—without production of heavy residual fuel.

Straight-run and cracked petroleum naphthas are converted to high octane gasoline, blending stocks, and aromatics by the efficient HOUDRIFORMING and ISO-PLUS HOUDRIFORMING Processes.

Complementing these processes, Houdry also offers catalysts, technical service, engineering, research, and economic consultation.

Write, outlining your interests or requirements, for a full description of specific ways Houdry may be able to serve you.

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Books . . .

and which appear inadequate for the full utilization of human potentialities.

Theory Y—The assumptions consistent with current research knowledge which could lead to higher motivation and greater realization of both individual and organizational goals.

(McGregor, Douglas, *The Human Side of Enterprise*, McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, N.Y., 246 pages, $4.95.)

Construction Manual

"Estimator's General Construction Manhour Manual" gives the reader an accurate and convenient method of estimating direct labor for complete general construction work in any given system, plant or location. The scores of manhour tables in the manual contain literally thousands of easy-to-use listings. These listings are valuable guides to estimating manhours in every phase of general construction work. They are the result of hundreds of time-and-method studies, coupled with actual labor costs on numerous projects.

The book points out how to arrive at composite rate using productivity efficiency and production elements. With the composite rate, manhour estimating can be applied to any general construction job.

(Page, John S., *Estimator's General Construction Manhour Manual*, Gulf Publishing Co., P. O. Box 2608, Houston 1, Texas, 218 pages, $10.)

Age of Oil

"This Age of Oil" traces the development of the oil industry in Australia from the time when kerosine ushered in a new era of illumination in town and country, to the revolution in transport, and indeed in our whole way of life, which follows the advent of the internal combustion engine.

The book deals also with the individual histories of the principal oil marketing companies operating in Australia today and with the emergence in the post-war years of a refining industry whose phenomenal development has contributed greatly to Australia's industrial strength.

(*This Age of Oil*, Petroleum Information Bureau, (Australia), 174 Swanton St., Melbourne, Australia, 204 pages, $3.65).

Equipment Inpection

"Chapter III, General Preliminary and Preparatory Work, of the Guide for Inspection of Refinery Equipment" covers scheduling, checking inspection tools and instruments, and preliminary work for major inspections.

(Chapter III, General Preliminary and Preparatory Work, of the Guide for Inspection of Refinery Equipment, Publications Department, American Petroleum Institute, 1271 Avenue of the Americas, New York 20, N.Y., 24 pages, $1.)

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The pump must match the application

The available range of our RPK Process Pumps offers the Oil Industry a selection that fully meets the fundamental requirement stated above.

The special characteristics of this pump are maximum reliability and economical operation at all operating points. Other features are the wide range of capacities and applications, the ease with which erection and disassembly can be carried out, and parts subject to wear renewed. The design includes a high factor of safety.

The parts particularly liable to deteriorate by wear are standardized for the widest possible range of sizes, and thus the maintenance of an adequate stock of spares is greatly facilitated.

Every type of service is catered for in respect of shaft sealing, which may be by means of the conventional packed stuffing-box or one of a great variety of mechanical seals.

KSB

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Who's Building...

Aerial shot shows: (1) New solvent dewaxing unit, (2) Major revamping work on the propane deasphalting unit, (3) Site of the new 85,000-bpd crude oil distillation unit, (4) New Udex benzene unit, at DX Sunray's Tulsa plant.

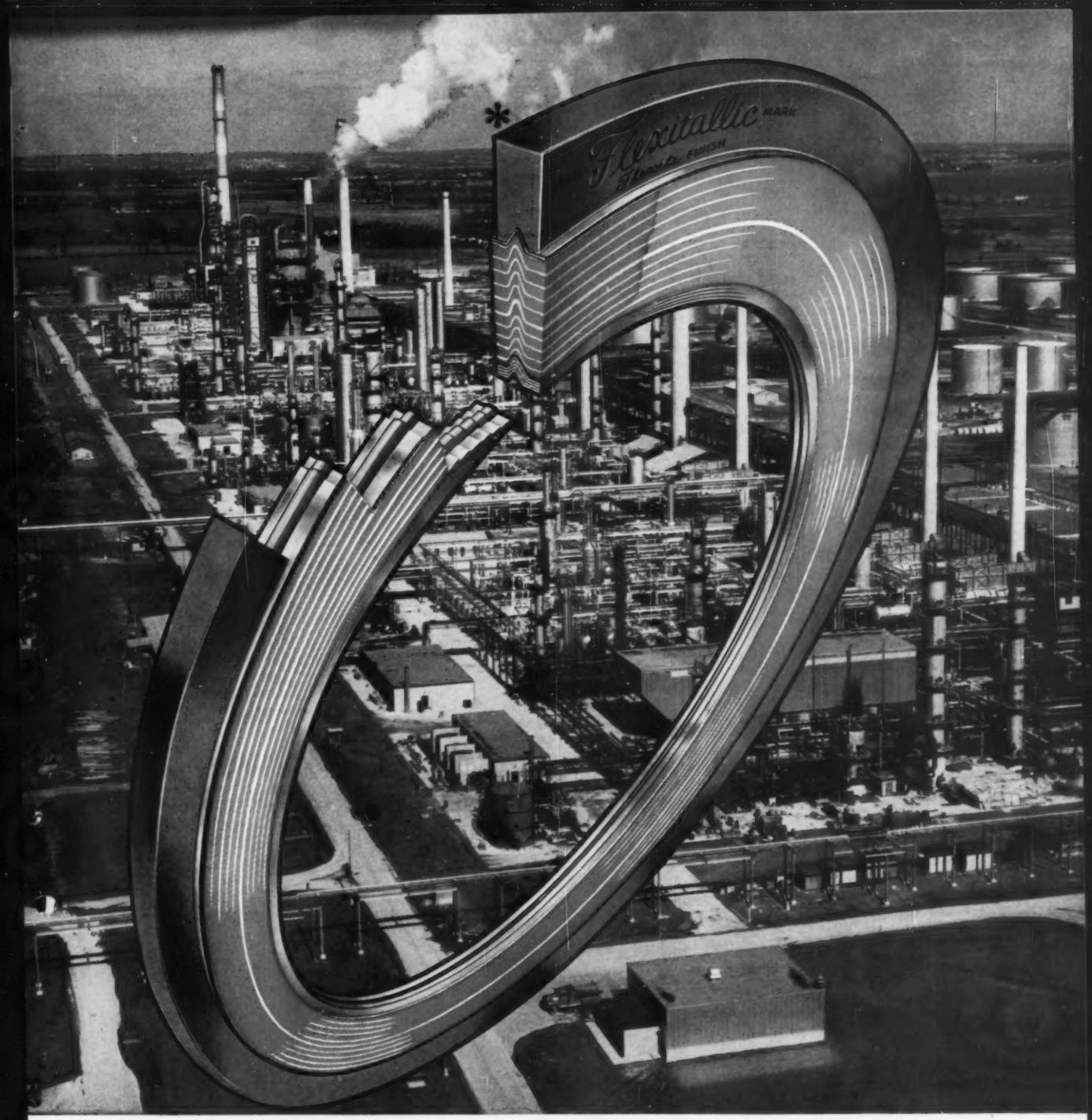
DX Sunray Completes Large Dewaxer

A $7-million dewaxing plant, the second largest MEK solvent dewaxer ever constructed, has been placed on stream at DX Sunray Oil Co.'s Tulsa refinery. This new unit represents an initial step in DX Sunray's modernization of its lube manufacturing facilities.

The plant incorporates three outstanding design features which furnish maximum flexibility, minimum operating cost and a maximum of simplicity in operation. The first feature incorporates a concurrent three-stage operation (1—dewaxing section, 2—wax fractionation section and 3—a finished wax repulp section). The first stage produces specification dewaxed or waxfree-lube base stock. The second stage charges the crude wax from the preceding stage, fractionates and deoils this material to produce a near finished product wax. The final or repulp stage removes the last traces of undesirable oil and soft wax from the product wax.

Second, the incorporation of the major machine power and users into a single integrated machine represents both an initial investment and operating economy. This machine includes a 7,500-hp gas turbine, a 2,000-ton refrigeration compressor and a vacuum compressor circulating inert gas. The fuel requirement, natural gas, for the gas turbine is 100,000 scfh at maximum load. This represents 100 million Btu per hour of heat released and converted to the 7,500 hp of machine energy. In addition, the exhaust of this machine is sent through a heat recovery boiler generating 32,000 pounds per hour of high pressure steam. Most of the power produced by the turbine is used to drive the propane refrigeration compressor generating the entire refrigeration needs of the plant at three temperature levels, —30° F., 0° F., and +30° F.

A second compressor utilizes the remainder of the gas turbine power to circulate inert gas blanketing the entire process system and generating the vacuum necessary to operate the large rotary dewaxing filters. The



End corrosion in gasket inventory

The gold Flexite Finish* for the metal gauge rings in Flexitallic Compression-Gauge Gaskets is new. It is highly corrosion resistant when exposed to severest weathering in open construction projects or in stock. The Flexite Finish provides for ease of identification and a clean, long-lived installation. Write for samples.

FLEXITALLIC GASKET CO., 8th & Bailey Sts., Camden 2, N. J.
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TRADE Flexitallic® MARK
SPIRAL-WOUND GASKETS
WITH Flexite FINISH

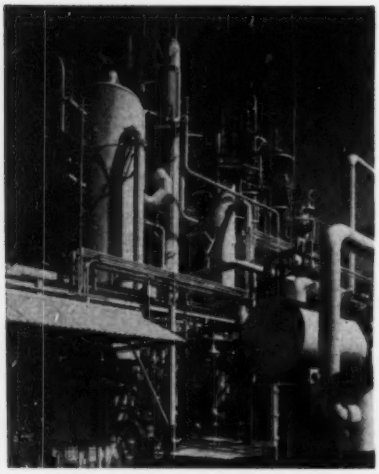
*The gold Flexite Finish is a development of the Flexitallic Gasket Co. (Originators of Spiral Wound Construction) – Register applied for on both name and color. Flexitallic Blue is our exclusive blue-dyed Canadian asbestos filler. Look for the blue and gold color combination as the mark of Flexitallic quality.

Building . . .

vacuum compressor circulates 19,000 cfm of inert gas with a vacuum pressure of 3 psia.

The third feature of the facility is the condensed and sequential process layout of the plant. The centrally-located control room is within a few seconds of any portion of the plant and contains an all-electronic control panel which monitors and controls the entire process. The plot is laid out in three general areas, the refrigeration-chilling area, the filter house area, and the distillation or solvent recovery area.

The plant incorporates several types of equipment not used in the general refinery. Among these are 28 double pipe exchangers. This special type of exchanger is designed to chill oil containing large amounts of wax, to solidify or crystallize



the wax in the presence of solvent, and maintaining a uniform flow of the solids and liquid produced. This requires the removal of a large amount of sensible heat reflected in the reduced temperature of the oil, wax, and solvent below the melting point of the wax, and at the same time remove latent heat of fusion produced when the wax goes from the liquid state to the solid state. The heat transferred in these units totals 40 million Btu per hour.

A second unusual piece of equipment in this plant is the dewaxing filters. They constitute the latest design in wax filtering equipment and the largest size filters in general use today. Each filter has 700 square feet of filter area, or a total of 8,400 square feet of filtering area for the 12 units. A mixture of oil solvent and wax crystals are fed to these filters where the major portion of solvent and oil is separated from the solid crystals of wax. Each filter handles approximately 4,000 bpd of oil and solvent, and 30-45 tons per day of wax.

Because of the large amount of heavy equipment, such as the gas turbine, the double pipe exchanger, and the filters, the entire plant had to be built on piling. In order to support the large loads involved, 600 concrete pilings were used.

The average production figures for this plant are:

Charge	8,000 bpsd
Dewaxed oil	6,800 bpsd
Soft wax	300 bpsd
Production wax	900 bpsd

The actual operation changes from stock to stock, the lightest neutral charge is 11,000 bpd and the heaviest bright stock reduces the charge to 6,800 bpd. Previously the refinery had three small dewaxing units for lube manufacturing and with the addition of this plant, these facilities will be abandoned.

Wax production was previously restricted to a limited amount of fully-refined and semi-refined paraffin waxes, and the production of a crude micro-crystalline wax. The new refinery facility can produce eight fully-refined base stocks ranging from a light paraffin wax to a high-melting-point micro-crystalline wax.

Constructed by Foster Wheeler Co., New York, the compact plant covers an area of 230 by 310 feet. Total work force on the unit is 18, while the refinery has a total force of 1,400.

Rexall Chemical Co. and El Paso Natural Gas Products Co. plan to construct a research laboratory and office facilities in Paramus, N.J.

Phillips Chemical Co. is adding facilities at its plant near Houston, Texas, to raise production of Marlex plastics to 100 million pounds per year, an increase of about one-third.

Standard-Vacuum Oil Co. and Shell Vietnam have filed plans with the Vietnam government to build a 22,000-bpd refinery. The plant would cost about $15 million. Caltex, which markets in Vietnam, is not included in the proposal.

Algeria is expected to put a small refinery on stream next June near Hassi Messaoud field. Initial production will be 1,000 bpd of gas oil, 600 bpd gasoline, 200 bpd kerosine, and 9,000 gallons daily of butane.

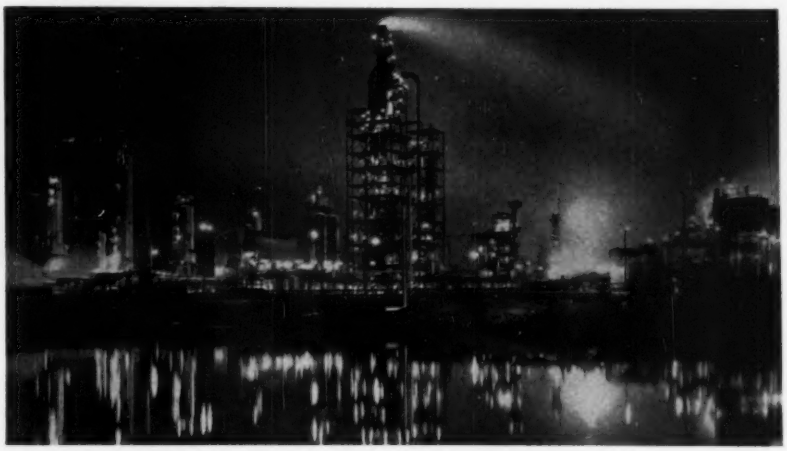
Signal Oil and Gas Co. will add a Hydeal unit to convert toluene into benzene at its Eastern States refinery at Houston, Texas. The unit will be built by Procon, Inc., and is expected to go on stream by the end of the year.

Union Rheinische Braunkohlen Kraftstoff A. G. has put its new urea plant at Wesseling, near Cologne, Germany, into operation. The unit has an annual capacity of 25,000 tons per year.

Odessa Natural Gasoline Co. and Warren Petroleum Corp. have begun construction on a gasoline plant in Midland County, Texas. The facility will have a maximum processing capacity of 20 MMcfd.

Allied Chemical Co.'s Plastics and Coal Chemicals Division is expanding its capacity for phthalic anhydride production at the company's Philadelphia plant. Completion is expected early next year.

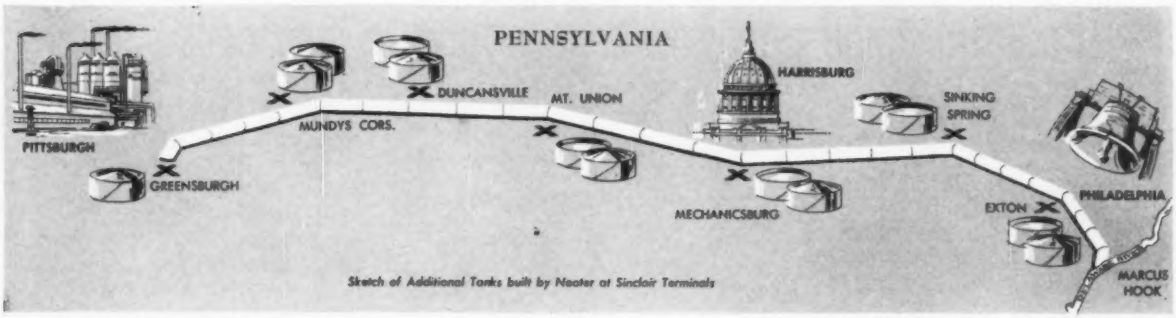
Dow Chemical Co.'s International Division plans to construct a plant in The Netherlands to produce phenol. The project will be carried on jointly with the Dutch firm, Staatsmijnen, a Dutch chemical company.



BP Canadian Refinery Completed

British Petroleum Co.'s first refinery in North America is complete and on stream. The new plant is located at Ville d'Anjou, 10 miles east of Montreal. The refinery's products will be distributed by road, rail, the Trans-Northern pipe line and by river, via the St. Lawrence River.

...added to Sinclair terminals on the Laurel pipe line



Sketch of Additional Tanks built by Nooter at Sinclair Terminals

To provide more petroleum products for communities along the Laurel Pipe Line in Pennsylvania, Sinclair Refining Company has modernized and enlarged seven of its storage terminals fed by the big line, which sweeps across the state from Sinclair's Marcus Hook, Pa., Refinery. Sinclair terminals in Pennsylvania now total 35,300,000 gallons capacity.

Thirteen new storage tanks were erected by Nooter for the terminals shown above, including both the cone roof type and the floating roof type. Nooter floating roof tanks feature a patented 2-point suspension seal hanger which provides a more positive seal, eliminates local abrasion, extends the life of the sealing ring and reduces maintenance cost.

Take advantage of Nooter's expanded services on bulk storage tank fabrication and erection, extending to all parts of the country. Check with Nooter on your next job, for cost saving estimates and dependable deliveries.

Write for Bulletin 158—Nooter Floating Roof Storage Tanks.

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Steel and Alloy Plate Fabricators and Erectors..."Boilermakers"

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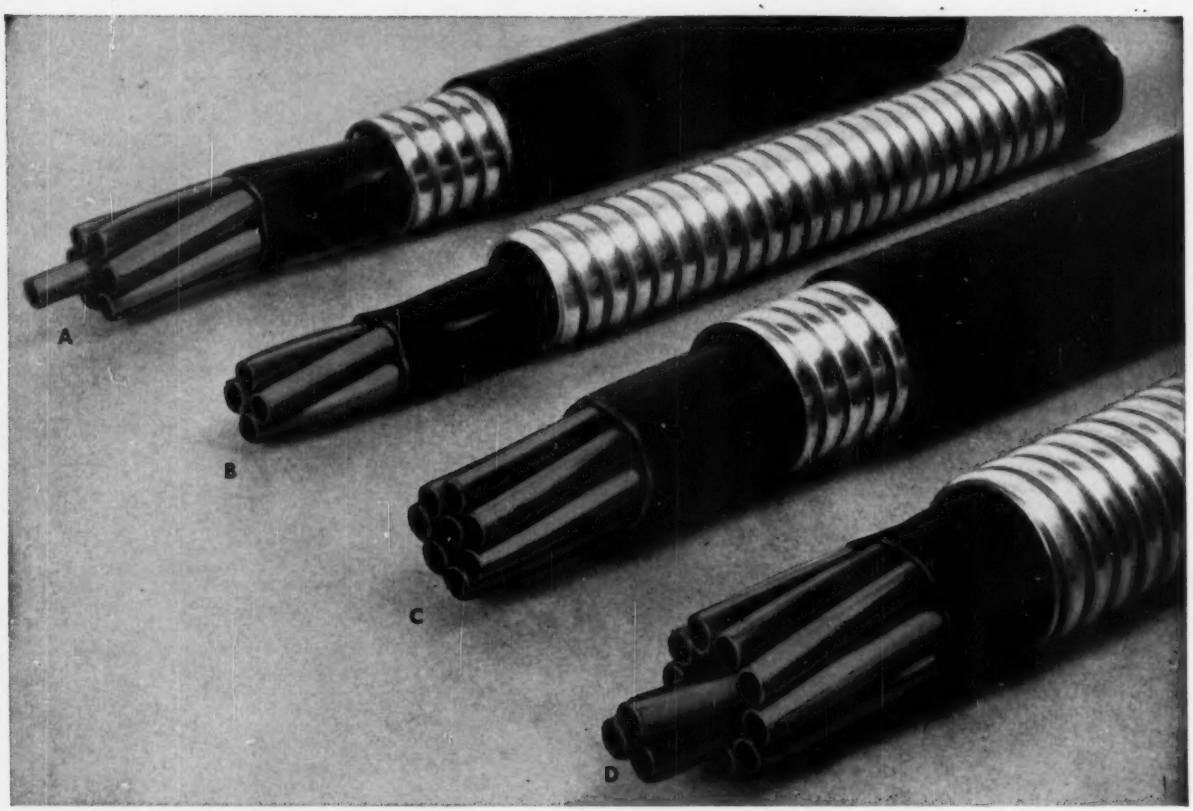
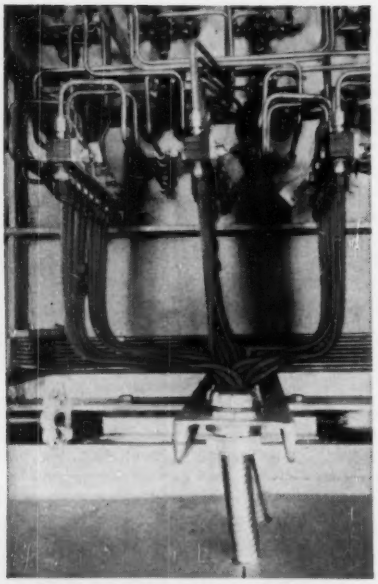


BAILEY ARMORTUBE is available with *A*, thermoplastic sheath over steel armor; *B*, thermoplastic sheath under steel armor; *C*, thermoplastic sheath over and under steel armor; or *D*, with just steel armor.

For its "Armortube" control system cables, Bailey specifies Anaconda precision copper tube in long coils



A TYPICAL INSTALLATION of Bailey Armortube in a large utility, indicating the large number of separate lines carried by two easily installed cables.

Armortube® flexible, armored, multiple-tube cable made by Bailey Meter Company, Cleveland, Ohio, has saved up to 40% of single-tube installation and maintenance costs in pneumatic, metering and control systems.

Armortube cable is available in lengths up to 1000 feet and in bundles of up to 19 individual ¼" O.D. copper tubes. Steel interlocking armor protects the tubes from mechanical damage and simplifies installation. In addition, various combinations of thermoplastic sheathing are available to provide further protection from moisture and corrosive atmospheres during and after installation.

CLEAN AND DRY. The copper tubes must meet rigid quality specifications, and Bailey has found that Anaconda copper tube consistently meets its requirements. Anaconda takes special care to see that inside surfaces are clean, smooth, and bright—free from dust, dirt, or metal chips which might interfere with the operation of delicate air and hydraulic circuits. Tube ends are sealed to keep out moisture and foreign matter during storage.

FLEXIBLE AND ACCURATE. Anaconda copper tubes are uniformly soft, highly flexible—for easy bending during installation. And they are accurate in size and shape.

LONG LENGTHS. For applications such as instrumentation, Anaconda can produce copper tubing in coils up to 2200 feet for ¼" O.D.—up to 1400 feet for ⅜" O.D.—up to 1000 feet for ½" O.D.

QUALITY TUBE AND CREATIVE TECHNICAL SERVICES. Whatever your requirements for precision copper tubing—instrumentation or capillary tubing, or restrictor tubes—Anaconda specialists can help you find the most economical way to do the job. For such technical assistance, see your Anaconda representative, or write: Anaconda American Brass Company, Waterbury 20, Conn. 6069L

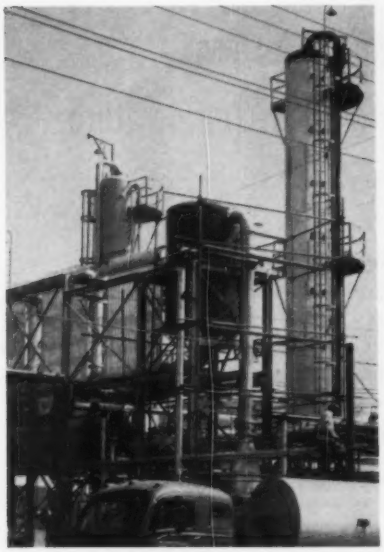
ANACONDA®
INSTRUMENTATION TUBING
Anaconda American Brass Company

For more data on advertised products, use Readers' Service Cards, last page.

Building . . .

Sulfur Recovery Unit On Stream at Lion Plant

A new sulfur recovery unit with a daily capacity of 15 tons of elemental



sulfur is on stream at Monsanto Chemical Co.'s Lion Oil Co. Division refinery, El Dorado, Ark.

Formerly a waste material in fuel gas used to heat steam boilers at the plant, the sulfur presently produced as a by-product will be sent in molten state to Monsanto's El Dorado chemical plant to be used in the manufacture of sulfuric acid. The acid is used in the manufacture of fertilizer, explosives, and many other organic and inorganic chemicals.

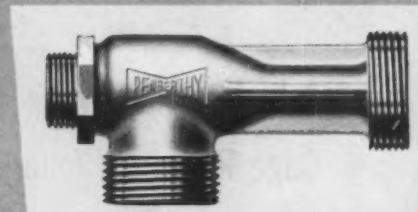
Sulfuric acid is used also in the treatment of product streams at the refinery, including its use as a catalyst in the plant's alkylation unit. Some of the acid produced at the chemical plant will be returned to Lion's refinery for use there.

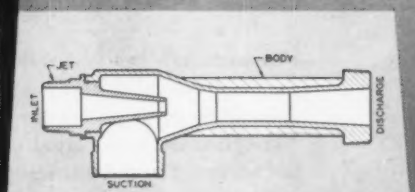
An important additional objective in the construction and operation of the new production unit is the prevention of air pollution from sulfur compounds which ordinarily would escape into the atmosphere in gaseous form.

United States Rubber Co's., Naugatuck Chemical Division will construct a $2-million pilot plant in Baton Rouge, La., for trial production of a new class of synthetic rubbers called the stereo regulars. The new unit represents a significant step beyond research work in the new materials which began about four years ago in the company's research center in Wayne, N. J., and in its Naugatuck Chemical Division laboratories in Naugatuck, Conn. The plant will be constructed on a site adjacent to the Chemical Division's plastics plant in the Scotts Bluff area of the Louisiana capital. The

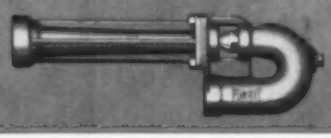
VERSATILITY

for applications unlimited





JET PUMPS by PENBERTHY



There's hardly a basic manufacturing or service industry that hasn't a use for Penberthy Jet Pumps. And the list of OEM products embodying Jet Pump applications is virtually endless, too. Small wonder, for wherever there's a fluid, vapor, gas or slurry handling job to be done . . . aerate, agitate, blend, circulate, dilute, exhaust, filter, heat, mix, pump or transfer . . . there you'll find an application for *versatile* Penberthy Jet Pumps.

And consider the advantages . . . small in size, light in weight . . . construction and operation simplicity . . . low initial cost, low installation cost, little or no maintenance cost. And in many cases Penberthy Jet Pumps can be utilized where mechanical pumps are impractical or uneconomical. Want more information? Send the coupon below or call your nearby Penberthy engineer today.

PENBERTHY MANUFACTURING COMPANY
Division of Buffalo-Eclipse Corporation
PROPHETSTOWN, ILLINOIS
SALES OFFICE: 2660 E. GRAND BLVD., DETROIT 11, MICH.

PENBERTHY
Dedicated to Quality Since 1886

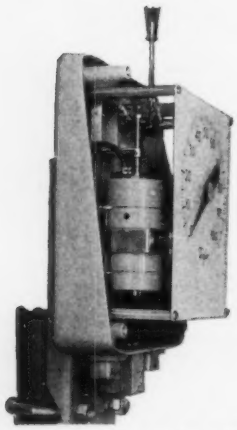
GENTLEMEN: Would like more information.
Please send your Jet Pump Catalog #512R.

NAME _____ TITLE _____
COMPANY _____
ADDRESS _____
CITY _____ ZONE _____ STATE _____

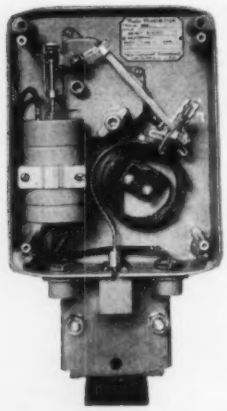
For more data on advertised products, use Readers' Service Cards, last page.

Now... Servo Power in

A high-accuracy, low-cost, motion-balance transmitter for Gage Pressure, Volumetric Pressure, Volumetric Load, Temperature



Diagonally-split case permits calibration adjustments to be made without removing dial.



Single-package pneumatics . . . servo-powered follow-up and relay valve, encapsulated movement and actuating element are easily removable, replaceable.

Taylor's new integrated line of pneumatic transmitters features servo-driven indication as an option on the indicating model. This provides ample power for process alarms—and other auxiliary functions such as digital encoders and potentiometers—with no loss of accuracy in the transmitted signal. Not only does it satisfy today's requirements . . . it provides for possible future needs. Other important features of the TRANSCOPE **210T** include:

- **High accuracy.** Transmitted signal is within ½% of the input signal. Indication is within ±1% of actual value.
- **Exceptional readability.** Big 11¾″ long concentric 270° scale can be read easily at 25-35 ft. Yet case measures only 7″ x 9″ x 4″.
- **Threshold sensitivity.** 0.1% of input span. Low-friction drive mechanism permits accurate handling of low-energy input signals.
- **Designed for easy maintenance.** Only 3 basic parts. A high quality encapsulated motion amplifier; single-packaged pneumatics . . . servo-powered follow-up and relay valve; interchangeable, time-tested actuating elements.
- **Lower inventories.** Benefits large users of instruments by utilizing actuating elements which are common with FULSCOPE® and other Taylor indicating, recording and controlling instruments.
- **Conveniently calibrated.** Diagonally-split case makes all adjustments easily accessible by merely removing cover.
- **Weatherproof case.** Special baked epoxy resin finish on die-cast aluminum case . . . designed for field installation.
- **Adaptable mounting.** Universal bracket permits wall or pipe installation.
- **Non-indicating model (211T)** has same performance as 210T except for process indication.

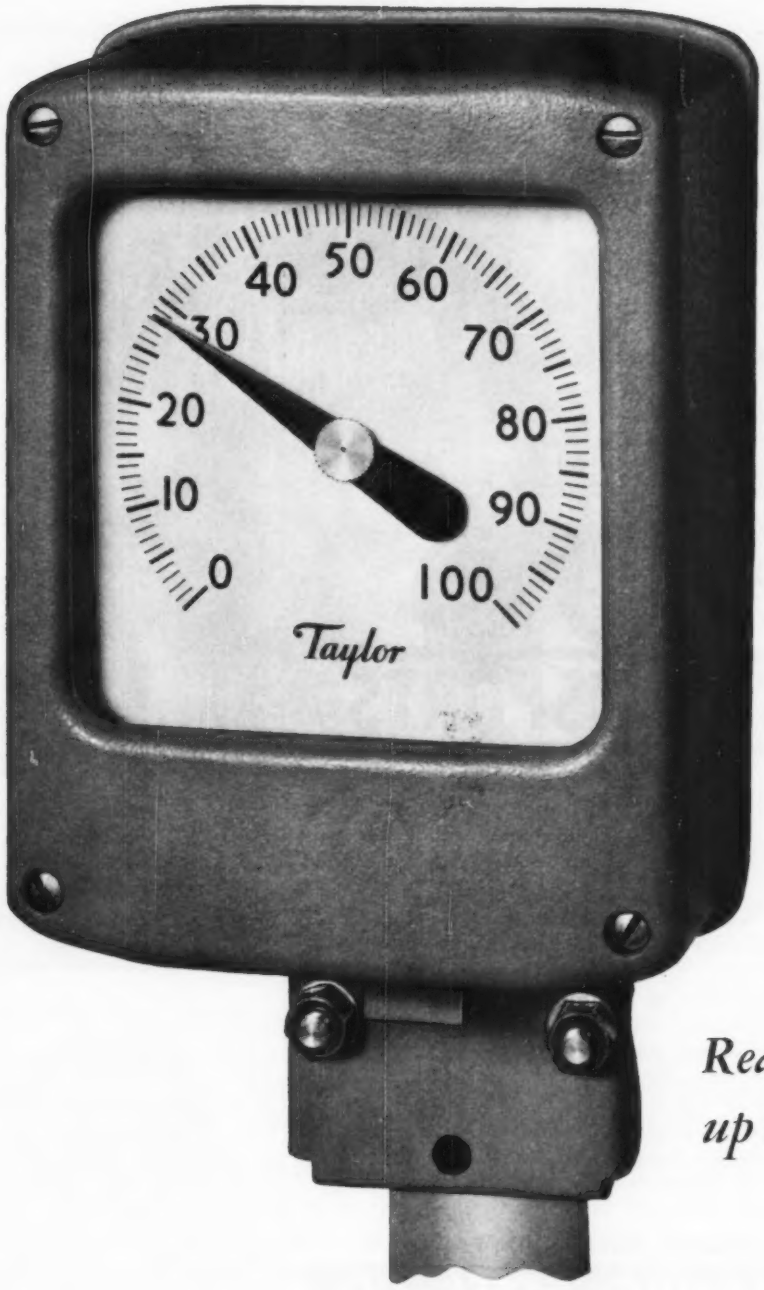
Ask your Taylor Field Engineer for a demonstration, or write for

Bulletin 98385

Taylor Instrument Companies, Rochester, N.Y., or Toronto, Ont.

Taylor Instruments

New Taylor TRANSCOPE® Transmitter



Read it up to 35 ft.!

MEAN ACCURACY FIRST

For more data on advertised products, use Readers' Service Cards, last page.

MOBILE GAS STORAGE

WHERE YOU WANT IT FAST WITH

GAS TRANSPORTS

"Mobile" is defined in the dictionary as being "characterized by ease of movement — capable of being readily moved about." This is a perfect explanation of the **principal** advantage of Taylor-Wharton Gas Transports.

Along with mobility, the transports afford semi-permanent storage of gases in tubes, with capacities up to 100,000 cu. ft. or more depending upon the size and type.

Each modern Taylor-Wharton Gas Transport consists of normalized seamless steel pressure vessels, inspected and tested to I. C. C. 3A-2400 specifications. The vessels are rigidly grouped and mounted on a special trailer chassis with either single or tandem axle. The transport is delivered ready for use, with tubes manifolded to a common outlet in a rear-mounted weatherproof cabinet.

Catalog No. 58 gives complete details on this practical system for flexible gas storage. Write for it today.

More than a Century in Harrisburg 2, Pa.

HARRISBURG STEEL CO.

Division of HARSCO CORPORATION

CYLINDERS

TUBES

FLANGES

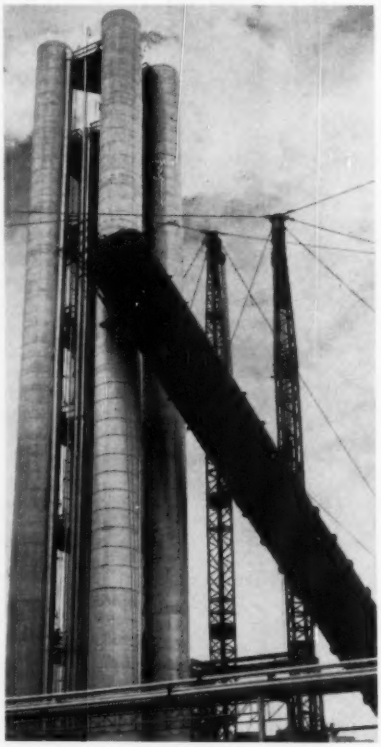
COUPLINGS

Building . . .

division also operates a synthetic rubber plant in that city. Engineering is now nearing completion. Construction is expected to start this year and the plant should be completed in the fall of next year.

Cosden Is Expanding Styrene Production

With the erection of a 159-foot styrene recovery column at its Big Spring, Texas, refinery, Cosden Petroleum Corp. has moved into the final third of its current expansion program which will treble the



company's styrene capacity to 70 million pounds annually.

The 300,000-pound column was inched into position beside the styrene unit's quadrangle of 200-foot ultra-fractionating towers.

Tied in with the expansion of styrene production is the erection of an Alkar Unit (UOP). The installation will manufacture ethylbenzene, styrene's precursor, by catalytic alkylation of benzene with ethylene. The entire project is scheduled for completion in mid-November, with on-stream anticipated December 1. Badger Manufacturing Co., Cambridge, Mass., holds the contract for design, engineering and construction.

Sto-Chem, Ltd., of Stoke Prior, Worcester, England, will build a latex plant. Crawford & Russell, Inc., Stamford,

For more data on advertised products, use Readers' Service Cards, last page.

Look to Parsons
FOR PERFORMANCE...

PROCESS ENGINEERING...*second to one*

Nature's complex processes... such as transpiration in plants and trees... are superior to those designed by man. But... for experience and for ability in process engineering of man's creations... Parsons is second to none. May we offer you proof of Parsons' performance? Write, on your letterhead, for Brochure 95/17.

The Ralph M. Parsons Company, Los Angeles. United States Offices: Houston, Huntsville, New York, Pasadena, Washington. International Offices: Ankara, Asmara, Baghdad, Bangkok, Cairo, Calgary, Dacca, Jeddah, Karachi, London, New Delhi, Paris, Teheran, Tokyo, Toronto.

WORLD-WIDE SERVICES: PETROLEUM-CHEMICAL ENGINEERING • ARCHITECT-ENGINEERING • CONSTRUCTION • ELECTRONIC SYSTEMS AND COMPONENTS • WATER DEVELOPMENT AND SYSTEMS • APPRAISALS AND ECONOMIC STUDIES • PLANT OPERATION • PERSONNEL TRAINING

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Anderson Quik-Flex Thermostatic Steam Trap— Guaranteed Freeze-proof for Two Years!

Guaranteed when properly installed and operated, this freeze-proof Anderson Quik-Flex Thermostatic Steam Trap is ideal for tracer lines, meter boxes, drips and other outdoor steam processing equipment used in chemical, refinery, solvent and other industrial plants.

Correct installation requires free condensate drainage on the discharge side. A cooling leg of at least three feet is a necessity to cool condensate, since thermostatic traps operate on temperature differential. The strainer should be installed in a down position to avoid freezes which could break the strainer body.

A TRAP FOR EVERY PURPOSE

THE V. D. ANDERSON COMPANY
division of International Basic Economy Corporation
1953 West 96th Street • Cleveland 2, Ohio
Please send without obligation your Bulletin No. 257

Name_____ Title_____
Company_____
Address_____
City_____ Zone_____ State_____

ANDERSON *QUIK-FLEX*

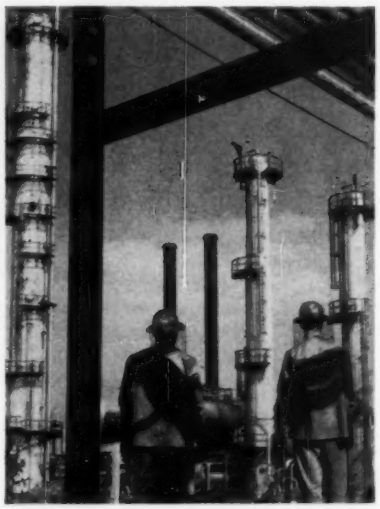
Building . . .

Conn., has completed the design of the facility, which will cost $2.5 million. Capacity of the unit will be 8 million pounds per year. A variety of latices of butadiene, styrene, and acrylonitrile will be produced. Sto-Chem is owned by United States Rubber Co. and Witco Chemical Co.

B-A's $3-Million Unit At Clarkson in Operation

Ontario's first hydrofluoric alkylation unit, which produces high octane components for premium gasoline, is now operating at British American Oil Co.'s Clarkson refinery, 20 miles west of Toronto.

The $3-million unit is B-A's second alkylation system and the first to use hydrofluoric acid as a catalyst. The company's first alkylation unit—a sulfuric acid type—went into operation in the fall of 1958 with the opening of B-A's sixth refinery at Port Moody, B.C., near Vancouver.



The 3,000-bpd Clarkson unit was constructed in response to increased demand for high-octane gasoline by Ontario's steadily rising automobile population. It produces high octane alkylate for blending with other gasoline components.

Primarily, the unit is comprised of a feed preparation system, two fractionating columns, acid contactors and a 154-foot iso-stripper tower—one of the tallest processing vessels of its kind in Canada.

Central contractors for the installation were Procon (Canada), Ltd. Extensive off-site construction such as tankage, piping and electrical systems were installed by Horton Steel Works, Ltd. and Humphreys & Glasgow (Canada), Ltd.

Pakistan Refinery, Ltd., has awarded a contract to Kellogg Inter-

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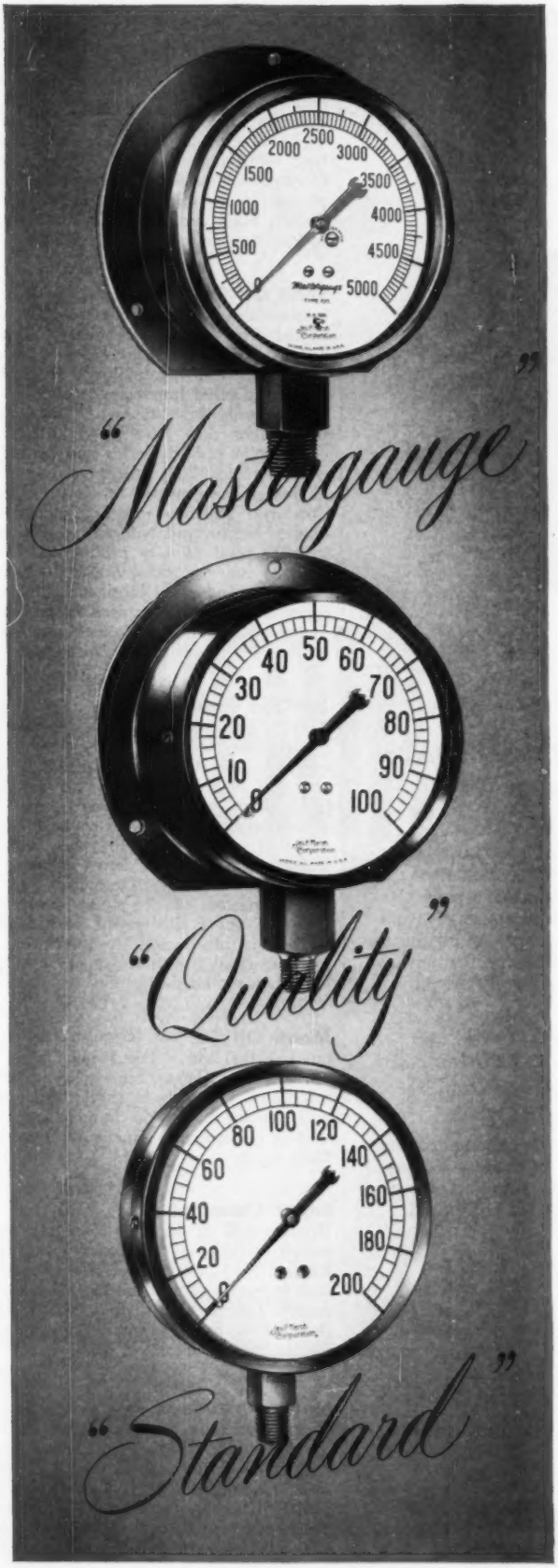

What pressure gauge for your particular need?

The clear-cut economical answer to your specific gauge problem is right here in the Marsh line. It is here because the Marsh line contains the world's most complete range of gauges in the three broad brackets of gauge applications.

THE "MASTERGAUGE" GROUP...for those extreme services that demand the ultimate in gauge precision, accuracy and stamina.

THE "QUALITY" GROUP...also for tough conditions, but less severe than the conditions served by the "Mastergauge" Group.

THE "STANDARD" GROUP...for the general run of pressure gauge services.

While these three brackets run a wide gamut of prices, the difference between them is not so much a matter of *grade* as a matter of *kind* and *purpose*. All gauges in all groups reflect Marsh precision and quality. Collectively they cover practically every conceivable gauge requirement.

The answer is in the catalog...but if you have a special problem let our engineering department work with you to select the most efficient, most economical solution to your problem.

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In stock at your nearest Supply House

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"THE STANDARD OF ACCURACY"

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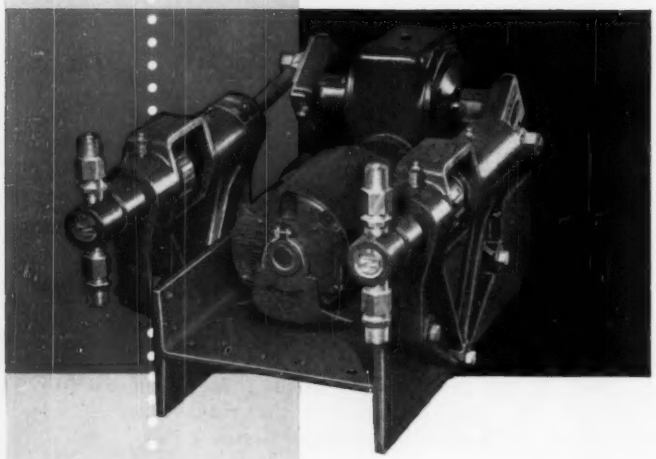
POSITIVE CONTROL OF MATERIALS IN MOTION BIF METERS FEEDERS CONTROLS



ONE PUMP PROPORTIONS ALKALINE, NEUTRAL OR ACID CHEMICALS

BIF *Proportioneers* **Adjust-O-Feeder**

Gives Application Versatility At Low Initial Cost

Meet changing requirements without changing your entire pump! Low cost changeover, with plug-in reagent ends, makes Model 1140 Proportioneer® extremely versatile in the capacities and types of chemicals it can handle. Compare these performance characteristics with competitively priced pumps:

Accuracy within ±1% of set rate.
Adjustment range of 15:1 (not 10:1 as most).
Capacity from 0.8 gph to 850 gph.
Discharge pressures up to 1340 psig.

You'll find opportunities for cutting costs and improving efficiency in process feeding when you consult B-I-F — manufacturer of the most complete line of solid and liquid feeders.

B-I-F **Industries**

BUILDERS-PROVIDENCE • PROPORTIONEERS • OMEGA
METERS • FEEDERS • CONTROLS / CONTINUOUS PROCESS ENGINEERING

For complete details on Model 1140 request Bulletin 1140.20-1. Write **B-I-F Industries, Inc., 412 Harris Ave., Providence 1, R. I.**

Building . . .

national Corp., London, a subsidiary of The M. W. Kellogg Co., to engineer and build a 35,000-bpd refinery near Karachi, Pakistan. The refinery will consist of a 32,500-bpd crude distillation unit, a catalytic reforming unit, and a hydrotreater. Construction is scheduled to be completed late in 1962. Purmah Oil Co., Caltex, Shell and Stanvac all participate in Pakistan Refinery, Ltd.

Shell Oil Co.'s first unit to hydrotreat lubricating oil stocks has gone on stream at the firm's Houston refinery. With a capacity of 6,500 bpd, the new hydrotreater will improve quality by removing sulfur and other impurities from low and high-viscosity index lube stocks and from transformer oils. It will upgrade their color, color stability, odor and oxidation characteristics. The process employs hydrogen under pressure at elevated temperatures. The new unit is designed for quality improvement only, and will not increase total refinery production. Low-viscosity index stocks are used in blending Shell's industrial lubricants, high-viscosity index stocks are used in premium motor oils, while transformer stocks are utilized for electrical applications.

SunOlin Chemical Co. has awarded a contract to Lummus Co., New York, for the engineering and construction of an ethylene and ethylene oxide plant. The unit will be adjacent to the Sun Oil Co. refinery at Marcus Hook, Pa. It is scheduled to be in operation late in 1961 and will cost approximately $20 million. The plant will have a design capacity of 225 million pounds of ethylene and 55 million pounds of ethylene oxide per year. Existing facilities will be modified to permit production of 12 MMcf of high-purity hydrogen and up to 1 MMcf of carbon monoxide per day.

Mobil Oil Co. has begun construction on a 20,000-bpd delayed coker unit at its Beaumont, Texas, refinery. Scheduled for completion early in 1961, the facility will convert heavy oil into such products as gasoline, light fuel oil and petroleum gases.

Enjay Chemical Co. a Division of Humble Oil & Refining Co. has completed facilities at the Bayway refinery, Linden, N. J., for the production of acetone in excess of 100 million pounds annually. This acetone is produced through the catalytic dehydrogenation of isopropyl alcohol.

Nalco Chemical Co. is building a chemical manufacturing plant in Saltillo, Mexico, and expanding production facilities of its German subsidiary, Deutsche Nalco-Chemie G.m.b.H. The Mexican plant will manufacture liquid, pellet and pulverized chemicals, and will also contain 8,000 square feet for office, plant

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We've
joined . . .

IMPERIAL EASTMAN

Happy occasion! The Imperial Brass Manufacturing Company of Chicago, producer of tube fittings and tools since 1905, and The Eastman Manufacturing Company of Manitowoc, Wisconsin, maker, since 1914, of rigid and flexible hydraulic power lines, have now joined hands. Happy occasion for us — happy occasion also, we trust, for our many mutual customers. Imperial-Eastman Corporation. General Offices: 6300 W. Howard St., Chicago 48, Ill.

IMPERIAL EASTMAN

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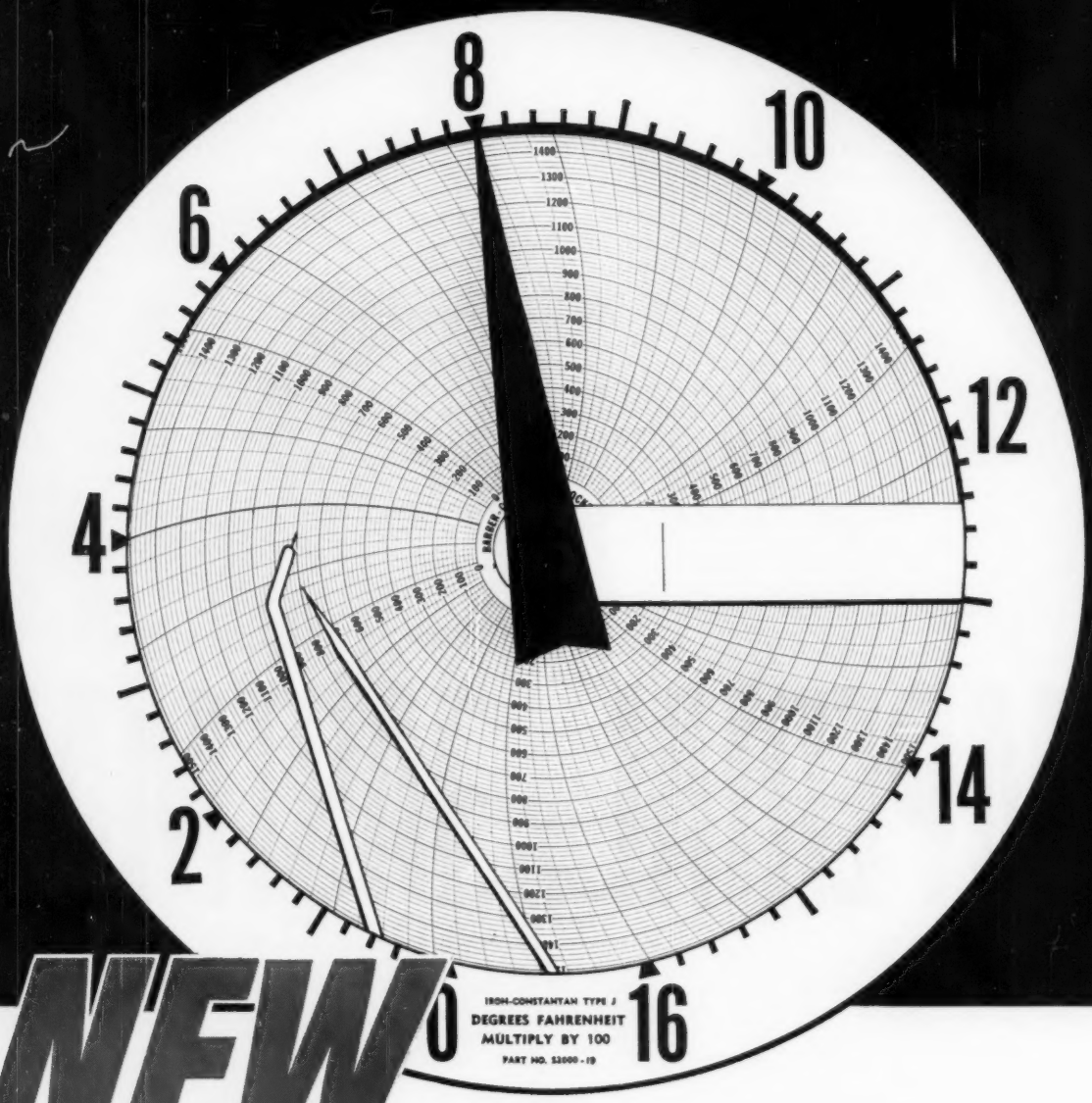

NEW

WHEELCO "DOUBLE-O"

Behind this dial, Wheelco presents a *new* instrument line at industry's most attractive price . . . the Double-O Models Recording and Indicating Controllers. Wheelco has integrated the most popular and the same famous Wheelco quality features into one full-size (not a miniature) electronic potentiometer controller line. And now, a volume production savings is passed on to you. Write today for complete details.

THE MARK OF QUALITY

BARBER COLMAN

Wheelco Instruments Division

BARBER-COLMAN COMPANY

Dept. K, 1597 Rock Street, Rockford, Illinois, U.S.A.
BARBER-COLMAN of CANADA Ltd., Dept. K Toronto & Montreal • Export Agent: Ad Auriema, Inc., N.Y.

Building . . .

and control laboratory facilities. February is the target date for completion of the plant. The German subsidiary is moving to enlarged quarters to permit greater production of liquid and pulverized chemicals.

Rohm & Haas Co. has begun erecting facilities for the manufacture of acrylic products at Louisville, Ky., on the site of an old butadiene plant. New construction at the site will cost about $12 million. Methyl methacrylate monomer, acrylic moulding powder and by-product ammonium sulfate will be produced. Construction is expected to be completed by mid-1961.

Foster Grant Co. plans to construct a multi-million-dollar polyethylene plant in Beaumont, Texas, adjacent to the Mobil Chemical Co. plant. The unit, expected to be completed by mid-1961, will use a high-pressure polymerization technique for the production of polyethylene.

Lone Star Gas Co. has started construction on a liquid hydrocarbon recovery unit near Madisonville, Texas. The plant is expected to be finished in December.

Reichold Beckacite, French affiliate of Reichold Chemicals, Inc., will construct a 10.5-million-pound-per-year maleic anhydride plant at Niort, Deux-Severs, France.

Hooker Chemical Corp. is installing a unit at its chlor-alkali plant in Tacoma, Wash., to produce perchlorethylene.

Oil-Chem Corp. will build a natural gas processing plant at McGregor, N. D., to cost $4 million. The plant will be designed to have an initial capacity of 20 MMcfd with expansion capacity to 30 MMcfd. Completion date is set for next spring.

Stauffer Chemical Co. plans to build a fertilizer plant in Eastern Utah by the end of 1962. The facility, to be located at Vernal, will use large deposits of phosphate ores in the area.

British Hydrocarbon Chemicals, Ltd., is planning a petrochemicals complex in South Wales. The site is close to British Petroleum's oil refinery at Llandarcy, near Swansea. Cost is estimated at $28 million.

Standard Oil Co. of California will begin construction on a complex of chemical plants to cost nearly $17 million at its Richmond, Calif., refinery. The complex will produce enough paraxylene to increase the refinery's output by 41 million pounds per year, as well as providing more than 100 million pounds per year of high-purity ortho-

Nicholson Thermostatic Steam Traps

These traps are only a fraction of your steam equipment cost . . . yet they can do a whale of a job in helping you to get full efficiency from that equipment even with varying pressures. Here's how.

Operating on a true balanced vapor-pressure principle, they discharge air, condensates and other non-condensables promptly, fully and intermittently. What's more, the bellows is located where it belongs . . . at the trap top . . . so that when live steam enters it contacts the bellows the moment the discharging condensate falls below the top of the inlet pipe. Thus, there is a constant water seal to prevent loss of live steam. This, plus the fact that valves and seats are accurately lapped for sure, safe shut off assures you of full thermal efficiency from every pound of steam. Capacity? These traps have it . . . up to six times greater than ordinary traps. Also since there's only one moving part . . . no links, pin, levers . . . your maintenance cost is next to nothing.

Get maximum Thermal efficiency from your equipment. Specify Nicholson Thermostatic Steam Traps. Immediate delivery.

W. H. NICHOLSON and COMPANY
12 Oregon St., Wilkes-Barre, Pa.
Offices in principal cities

Send for Catalog

W. H. NICHOLSON and COMPANY
12 Oregon St., Wilkes-Barre, Pa.
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STREET_____
CITY_____ STATE_____

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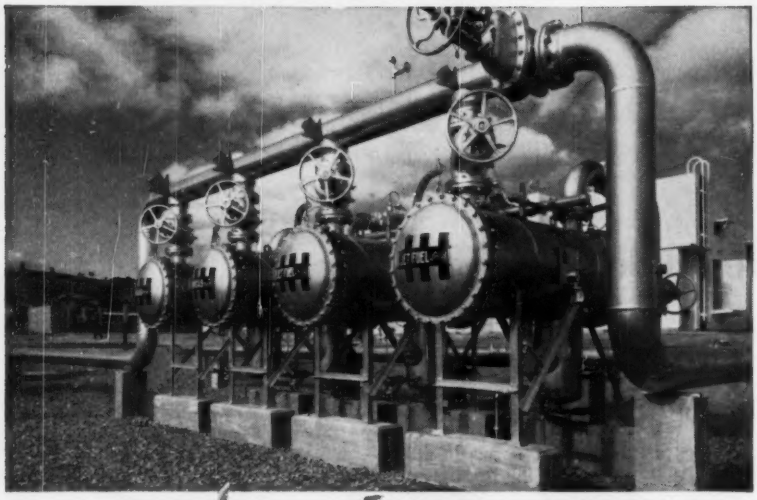
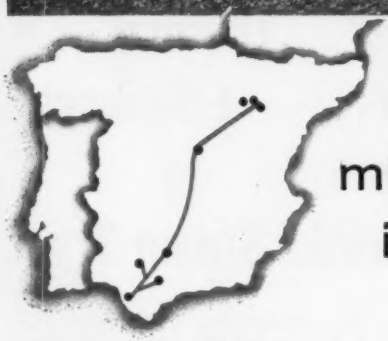


Markowitz Bros. Inc., Mechanical Contractors
Miami, Florida



on the military pipeline in spain...

WELDOLETS were used for all branch connections on pumping station piping

Reinforced branch connections constructed with Weldolet Welding Fittings provide assurance of quality workmanship at the critical branch connection.

Savings in purchase price and construction on this project alone were high in the six figures. Piping designers and contractors who are interested in similar savings on their jobs are invited to write us for the Bonney Spanish Pipeline Brochure.

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BRAZOLETS®
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CARBON STEEL
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for all services

BONNEY FORGE and TOOL WORKS
ALLENTOWN, PENNSYLVANIA

Building . . .

xylene. Process design will be handled by California Research Corp. Construction will be directed by the company's engineers.

Gulf Oil Corp. has awarded a contract to some French companies and Procon, Inc., to construct a 10,000-bpd refinery in the Philippines.

DuPont de Nemours (Nederland) N.V. is building a plant to process acetal resin in Dordrecht, The Netherlands. Production at the plant, which is costing several million dollars, is expected to begin in 1962.

Shell Chemical Co. has completed the first stage of an expansion at its urea manufacturing facilities at Ventura, Calif. The final stages of the project will be completed next spring.

Houston Chemical Corp. has awarded a contract for construction of a $10-million project on plants to make tetraethyl lead and tetramethyl lead at Beaumont, Texas. The units, which are expected to go on stream by September 1961, will be built by Singmaster & Breyer, New York. Houston Chemical will rank third in the United States as a producer of these gasoline additives after the expansion is completed.

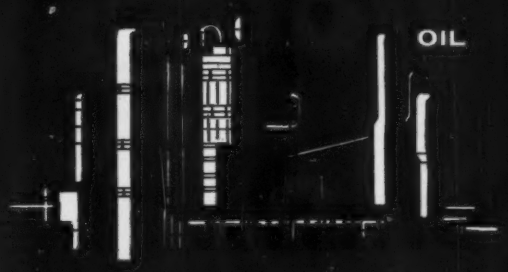
Dow Chemical Co. is joining with Union Quimica del Norte de Espana (Unquinesa) to construct a petrochemical complex in Spain. Present plans include building a cracking unit to produce ethylene and propylene. Dow will furnish technological know-how, engineering and marketing assistance.

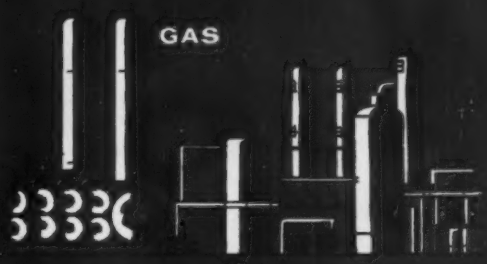
W. R. Grace & Co. is expanding its Dewey and Almy Chemical Division's Owensboro, Ky., plant. The unit produces synthetic rubber and polyvinyl acetate emulsion. The expansion will cost about $1 million.

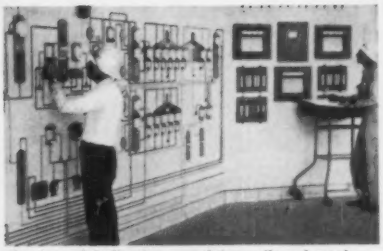
Asahi Chemical Industry Co. is building a $4-million acrylonitrile plant in Kawasaki, Japan. The plant, expected to be completed next May, will have a capacity of up to 15 tons per day.

Powerline Oil Co. is installing the first hydrocraking unit using UOP's Lomax process at its Santa Fe Springs, Calif., 15,000-bpd refinery. The process is scheduled to go into operation early in 1961.

Sinclair Oil & Gas Co. has expanded its gas products plant number 25 in Hardin County, Texas, to increase gas volume from 35 to more than 50 MMcfd. The enlarged plant will produce about 105,000 gallons daily of natural gasoline, propane, butane and other liquefied pe-

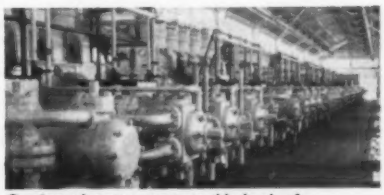






Omniguard indicating panel is easily adapted to miniaturized instrument panel installations for central control.

Detectors provide continuous temperature monitoring of drive motors for shipping pumps.



Omniguard system protects this bank of compressors installed at a natural gas cycling plant.

Oil company power plant uses Edison Omniguard system to protect generating equipment from overheating.

THOMAS A.

EDISON

omniguard system provides reliable, flexible temperature monitoring for oil, gas and petrochemical industries

Throughout your process, wherever temperature is critical, the Edison Omniguard system can protect vital equipment and output quality. It is the simplest and most flexible temperature monitoring system devised.

Plug-in detector units may be installed at key points throughout the process. They can be added or switched without disturbing the system. Typical detector locations include motor and motor bearings in shipping pumps, compressors and generating stations. Individual alarm settings on each point can be changed at any time without special tools.

Indicating panel can be located in central control room, for complete overall process monitoring by a single individual. Alarm system positively identifies trouble point.

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Edison engineers will be happy to provide assistance in designing the most efficient system to meet your requirements.

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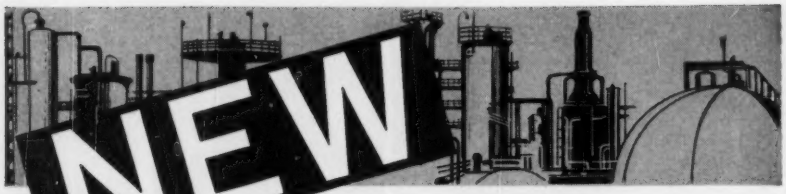

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• METERING ACCURACY OF ±1%

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New 200 Series Simplex model can pump up to 812 gph. Duplex model has double this capacity. Maximum pressure of 10,000 psi.

Easy, inexpensive operation is assured by these quality features:

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- Interchangeable liquid ends for greatest adaptability in the field.
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- NEMA frame motors.

Precision built 200 Series pumps handle a wide variety of "tough," corrosive materials. In Chemical Processing, Refining and Boiler Feed operations, the pumps assure highest accuracy in feeding precisely metered fluids in virtually all ratios, with flow, temperature, pressure, conductivity, PH and other controlled process variables.

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Building . . .

troleum gases. The expansion includes the addition of a booster, changes to the plant processing equipment, and more field gathering lines.

Esso Standard Division, Humble Oil & Refining Co., plans to increase its benzene capacity at the Baton Rouge, La., refinery from 9 million gallons to 24 million gallons per year. Completion is slated for December.

Dow Badische Chemical Co., Freeport, Texas, will construct a butanols plant to produce n-butanol and isobutanol. Completion is expected for early 1961.

BASF, BAYER, Hoechst, and the engineering firm Friedrich Uhde have joined to furnish the know-how, engineering and processes to set up a $25-mil-

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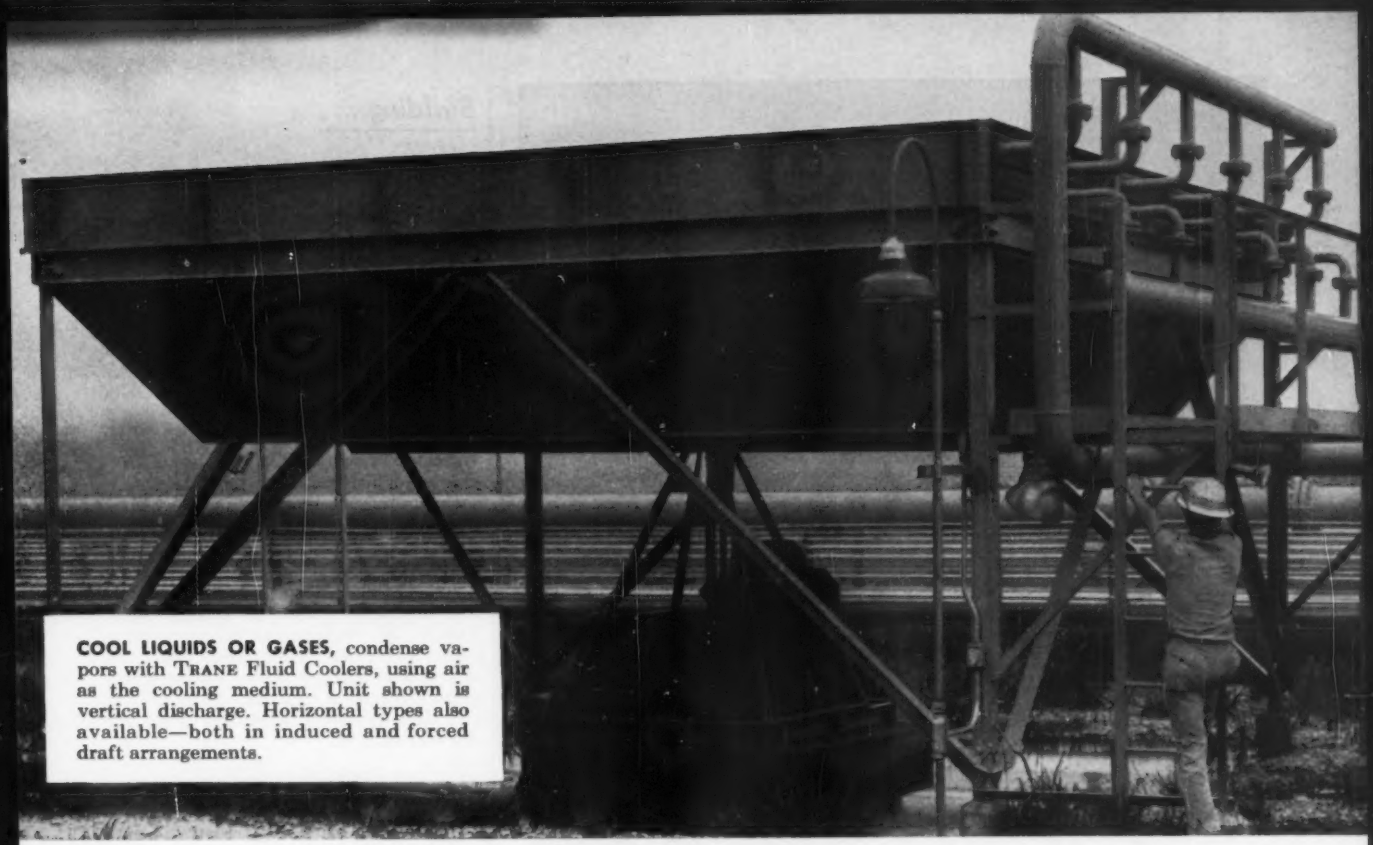

COOL LIQUIDS OR GASES, condense vapors with TRANE Fluid Coolers, using air as the cooling medium. Unit shown is vertical discharge. Horizontal types also available—both in induced and forced draft arrangements.

Lower erection costs, operating costs ...with versatile Trane Fluid Coolers!

Air-cooling now solving water supply problems for many refineries, petrochemical and natural gasoline plants

More and more engineers and plant designers are finding that *air-cooled heat exchangers* eliminate water supply and maintenance problems encountered with conventional cooling towers. These engineers report a substantial net reduction in over-all cooling costs and water consumption. Here are some of the ways TRANE Fluid Coolers are helping to solve heat transfer problems in many refineries and plants:

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- **Superior performance.** TRANE Coolers available with Admiralty stainless and carbon steel tubing to meet the most exacting specifications. Units are now in use in Canada and Bermuda—meeting extreme weather conditions. They also solve the problem of corrosion caused by salt-air atmosphere.

WANT MORE FACTS?

New Catalog S-395 has complete specification and application data on TRANE Fluid Coolers. For your copy, write TRANE, La Crosse, Wisconsin. Or just call your nearby TRANE Sales Office.

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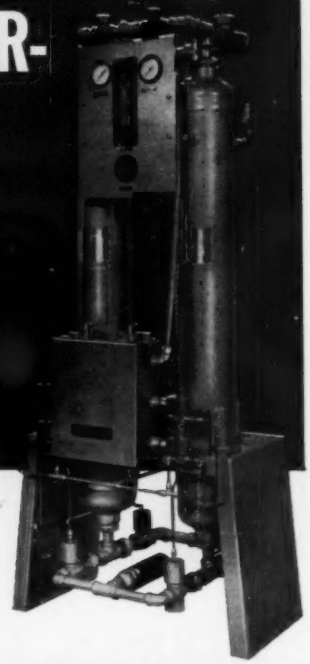
LOW COST, DEPENDABLE INSTRUMENT AIR-

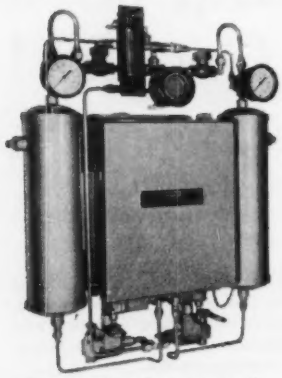
TRINITY

Heat-Les

DRYERS



Increase dependability and accuracy of measurement and control in your system by specifying a dependable Trinity Heat-Les Dryer. These amazing dryers, operating on a principle so simple, yet so efficient, are establishing unparalleled operating records in over a thousand installations.



Trinity Heat-Les Dryers are available in standard models ranging from 2 SCFM to 5000 SCFM. Units up to 200 SCFM are available from stock

- ★ Low initial cost
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- ★ No increase in effluent gas temperature
- ★ Low installation costs
- ★ Low operating and maintenance costs
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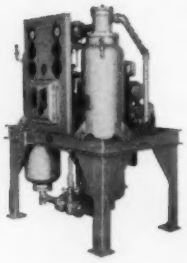
ALSO HEAT-REACTIVATED DRYERS

Trinity also offers a complete range of capacities in heat-reactivated type dryers of an advanced design, offering the greatest economies and performance for this type dryer... **WRITE FOR COMPLETE TRINITY DRYER AND ACCESSORY TECHNICAL MANUALS...**



TRINITY **World leader in dry gas/air systems**

Heat-Les Dryers • Heat-reactivated Dryers
Thermocouples and Thermowells

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Building . . .

lion plant in India to produce toluene, benzene, naphthalene, and xylenes. They will each receive shares in a corporation established by the Indian government to operate the plant.

Tidewater Oil Co. has increased its gas liquids production from 32,886 gallons to 53,298 gallons daily at the firm's Venice, La., gas plant. Expansion in gas capacity amounted to 20 MMcfd. Delta Engineering Co. was the contractor.

Mobay Products Co. has begun production of polycarbonate resin on a commerical basis at its plant in New Martinsville, W. Va. Mobay Products is a subsidiary of Mobay Chemical Co.

Sun Oil Co. is going to build an $8-million napthalene plant at Toledo, Ohio. The M. W. Kellogg Co. has received a contract for the engineering and construction of the project, which is expected to have a capacity of 100 million pounds per year. Completion is set for the end of 1961.

Standard Vacuum Oil Co. proposes to construct a $9-million lubricants plant at Bombay, India. The plant would be set up on a 50-50 basis with the Indian government or another Indian investor. The facility would process feedstock from Stanvac's Bombay refinery to produce 700,000 barrels per year of high-quality oil for automotive and industrial use.

Royal Dutch/Shell and Montecatini Oil Co. have joined forces to form the subsidiary, N. V. Rotterdamse Polyolefinen Maatschappij. The new company will build and operate a polypropylene plant in Rotterdam, The Netherlands.

Hudson Engineering Co. will construct a gas processing plant for oil and gas producers in the Port Acres Field of Jefferson County, Texas. The $4-million plant will process up to 150 MMcfd of gas.

Idemitsu Kosan Oil Co. plans to build a refinery and petrochemical plant near Tokyo, Japan. The company is a Japanese independent holding a contract for 20,000 to 30,000 bpd of Russian crude for six years.

Esso Petroleum Co. and Shell Oil Co. have both been refused rights to construct petrochemical plants in Spain. Spanish officials have already granted such rights to two other groups.

Union Carbide de Brasil plans to expand its polyethylene plant production at Santos, Brazil, from 9 million to 24 million pounds per year.

B. F. Goodrich Chemical Co. plans to build a plant in Colombia to manu-

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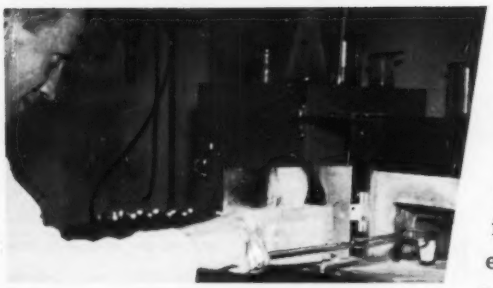
97% BaO!

soaring FMC quality

suggests a new look at bariums!



FMC BaO now provides an extremely pure source of barium values in a highly reactive form. Besides offering interesting new potentials in barium applications, it provides processing advantages for present users.

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STRONG is the word for Centrifugally Cast Pipe

RESISTANT is the word for Chrome-Nickel Alloying

. . . and the alloying is selected so that you will get high resistance to corrosion or high resistance to extreme heat or high resistance to both, as you require.

Centrifugally Cast Pipe has been a major DURALOY item since 1933 when we pioneered such high alloy castings in this country. Standard pipe production is in the following classification:

Outside Diameter	Minimum Wall	Length
2½" to 3"	1/4"	88" maximum
3" to 6" Inclusive	5/16"	110" maximum
Over 6" to 12" Inclusive	3/8"	168" maximum, 24" minimum
Over 12" to 14" Inclusive	7/16"	168" maximum, 24" minimum
Over 14" to 20" Inclusive	1/2"	180" maximum, 48" minimum
Over 20" to 24" Inclusive	1/2"	88" maximum
Over 24" to 32" Inclusive	5/8"	80" maximum

The strength of Centrifugally Cast Pipe comes largely from the exceptionally uniform dense grain structure.

If you require a gas or liquid pipe line or a process tube requirement calling for high strength plus high resistance to corrosion and/or temperatures in the piping, DURALOY Centrifugally Cast Pipe will meet your specifications with complete satisfaction. This is the record of our castings in industry for many, many years.

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Building . . .

facture vinyl plastic materials. Goodrich will join forces with a Colombian firm to construct the facility, which will be near Bogota. Construction is to begin soon and production is expected to start in 1962.

Shell Oil Co. is considering expansion of its 40,000-bpd refinery at LaSpezia, Italy. The Italian government has authorized Shell to purchase rights in the plant.

Plymouth Oil Co. is planning to build a hydeal unit to produce 15 million gallons of benzene per year at its Republic Division refinery at Texas City. Completion is set for May 1961.

Gulf Oil Corp. will build a lubricating oil facility at its Port Arthur, Texas, refinery. Bechtel Corp. will construct the 13,000-bpd plant. The installation will be constructed as twin units, each with a designed capacity of 6,500 bpd. Designed to handle a dozen different feed streams from existing operations, the new units will be able to maintain maximum flexibility by quickly switching from one source to another.

STATEMENT REQUIRED BY THE ACT OF AUGUST 24, 1912, AS AMENDED BY THE ACTS OF MARCH 3, 1933, JULY 2, 1946 AND JUNE 11, 1960 (74 STAT. 208) SHOWING THE OWNERSHIP, MANAGEMENT, AND CIRCULATION OF PETROLEUM REFINER, published monthly at 3301 Buffalo Drive, Houston, Texas, for October, 1960.

1. The names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, Wm. G. Dudley, 4742 Banning, Houston, Texas; Editorial Director, Silas B. Ragsdale, 1636 North Blvd., Houston, Texas; Editor, George B. Gibbs, 9214 Timberside, Houston, Texas; Chrm. Editorial Committee, Dr. John J. McKetta, 4702 Fairview, Austin, Texas; Managing Editor, Wallace Fitzgerald, 5423 Lymbar, Houston, Texas; Business Manager, Robert M. de Sombre, 4410 Ingersoll, Houston, Texas.

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5. The average number of copies of each issue of this publication sold or distributed, through the mails or otherwise, to paid subscribers during the 12 months preceding the date shown above was: 24,202.

R. M. de SOMBRE
Business Manager

Sworn to and subscribed before me this 28th day of September, 1960.

P. J. AUCOIN
(Seal) Notary Public in and for Harris County, Texas. (My commission expires June 1, 1961)

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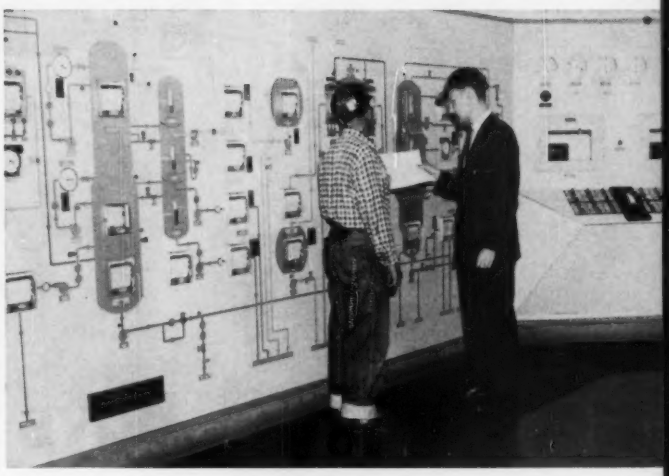
What's Happening...

Electronic Computer Tells How Crude Unit Can Top Efficiency

Standard-Indiana has first computer to control complex crude distillation unit



Schematic control panel operates the unit at peak efficiency.

Every four minutes a digital computer reads 196 instruments; every 20 minutes it types out orders that originate from about 75,000 stored instructions. These orders guide operations of the 140,000-bpd crude-oil distillation unit at Standard Oil Co.'s (Indiana) refinery, Whiting, Ind.

This is the first time a computer system has so completely controlled any industrial operation as complex as the giant Standard Oil distillation unit, according to John E. Swearingen, president of Standard-Indiana, and Gilbert E. Jones, president of International Business Machines Corp.'s Data Processing Division.

Every 24 hours the distillation unit separates crude oil into 10 different streams which supply 6 million gallons of products, most of which are further processed before they become finished products, such as gasoline.

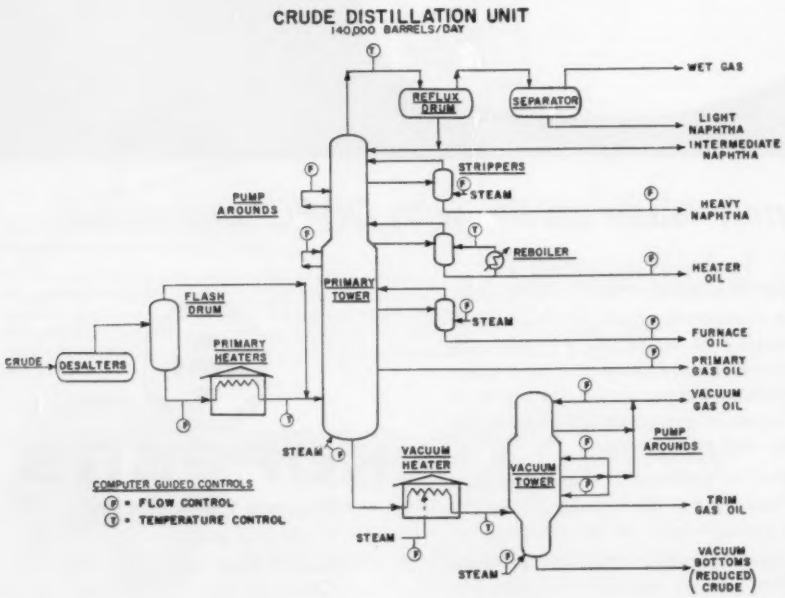
Signals from the 196 instruments are transmitted over a telephone line to the computer housed in Standard Oil's technical center. The machine's computations are sent back to the control room and automatically printed on a typewriter. They guide the men in charge in adjusting up to 19 controls as needed to maintain top operating efficiency.

Such close guidance was impossible before the computer program was developed. Calculating similar data manually would give the needed information too late to be useful, Swearingen and Jones emphasized. Furthermore, they said, the computer handles the complex task with time to spare for work on other scientific assignments.

Swearingen reported that crude-oil distillation is an ideal first choice for computer control because it is basic to all refinery operations. Because distillation is the commonest refinery operation, the computer control techniques developed in this project will have wide future applications for Standard Oil, he said.

"Plans are already developed for a computer installation on an Ultraforming unit, which employs our key process for raising octane number of gasoline. Catalytic cracking and alkylation are other likely prospects currently under study for control by computers," Swearingen said.

As tests on the smaller still progressed, Standard Oil began operating the number 12 crude-oil distillation unit



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Once there was a manufacturer who looked everywhere to find tubing that would solve a knotty production problem. But tolerances were so close, specifications so rigid, that conventional sources couldn't help him. Then he read about Michigan Seamless' TAILORED TUBING—made by a specialty mill with 33 years' experience! Result? Our production-engineering-metallurgical group quickly presented a solution that was "music" to the ear of this worried manufacturer! If you have a tough job for tubing, write or wire, we'll supply the answer!

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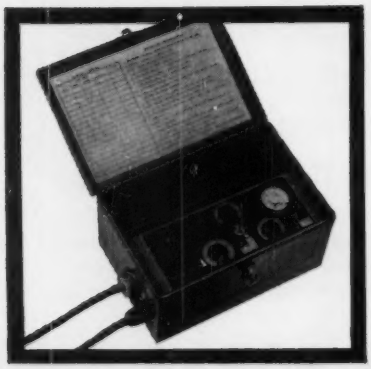
ALSO Electric Control ...Tube Expanders... and Related Accessories



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Y9-3

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LAGONDA PLANT, Springfield, Ohio

Happenings . . .

at the Whiting refinery in May, 1959. Some 90,000 bpd are removed as overhead and sidestream products in the primary tower of this unit. These products are wet gas, three naphtha streams, two distillate fuels and light gas oil. The remaining 50,000 bpd of the crude charge is fed from the bottom of the primary tower to the vacuum tower. Products removed from the later tower are heavy gas oil as a sidestream and reduced crude as a bottom product.

When it began operation last year, the number 12 crude still featured more instrumentation techniques. Operators were able to maintain normally stable operation and made highly-acceptable products at reasonable throughputs. However, there was no assurance that the plant was running at highest yield of the more valuable petroleum products or with most efficient use of fuel. Additionally, conventional instruments could control only one variable according to some relatively simple objective. For example, a temperature could be controlled at a constant value or a flow regulated at a constant ratio to another flow.

The results of the computer-control trials at the smaller crude distillation unit pointed the way to the solution of those problems and it was decided to continue the development on a fully-automated basis on the larger unit where payoffs would be greatest.

Control System

With important variables clearly identified, the joint study team proceeded to apply computer control to the number 12 crude still. Required were automatic means of collecting data, interpreting the information into control actions, incorporating a program for entering the data into a computer and getting the output back to the operator.

An annex 25 feet by 17 feet was constructed alongside the number 12 still control building to house equipment for monitoring the process. A terminal unit, with no active components, interconnects the process and the data processing equipment. It matches process signals and also serves as a reference junction for thermocouple signals.

Process data, still in analog form, pass to a solid-state logic unit which sequentially scans the 196 inputs in about 75 seconds, amplifies these signals and converts them to digital form.

Digital information then passes to an input/output unit which transforms the signal into a code suitable for transmission over a single pair of telephone lines to Standard's Administration Building one mile away.

When the process data arrive in the building's computer room, cards may be punched, although this is not necessary, and at the same time the information may enter directly into a computer. This computer is used for process control calculations on an "interrupt" basis. It has a "Realtime Package" and therefore can receive or send digital information in electrical form as opposed to conventional

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Petro-Tex C_4 Hydrocarbons

Available in tank cars, tank trucks, barges and cylinders

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Highest Commercial Quality from the World's Largest Non-Captive Production.

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Highly reactive alphaolefin 95+% pure with low moisture and no butadiene whatsoever.

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Clear water-white mixture of 2,4,4-Trimethylpentene-1 and 2,4,4-Trimethylpentene-2.

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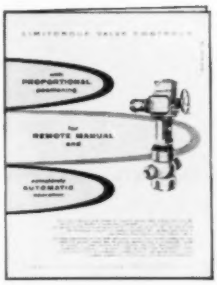
LimiTorque

VALVE OPERATORS

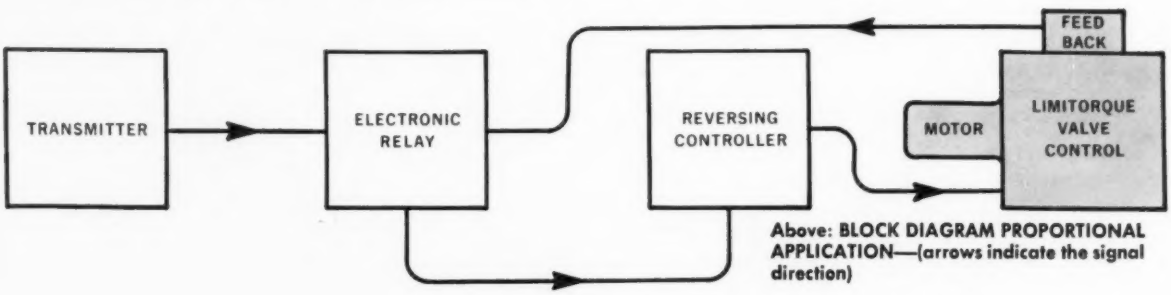
with Proportional Positioning for Remote Manual, and Completely Automatic Operation

The growing demand for complete process control systems to assure the centralization of performance responsibility in a single source, is successfully accomplished by systems employing LimiTorque (some of which are outlined in Bulletin #6-60 offered here). The same dependability and accuracy that has made the name LimiTorque so widely used and favorably known throughout the World on all types of installations, is maintained in these modern all-electric actuator systems.

Full range proportional operation of the final control element from remotely located electronic transmitters, provide answers that the process engineers need, to automatically throttle in response to process variables such as pressure, flow, level, density, weight, thrust, temperature, position, etc. Components employed in the LimiTorque system are chosen for dependability with the elimination of complex circuits and special electrical power supplies. Inquiries are invited to meet the exacting service requirements.



Be sure to send for this New Bulletin 6-60 which fully describes and profusely illustrates LimiTorque with Proportional Positioning accessories.



Above: BLOCK DIAGRAM PROPORTIONAL APPLICATION—(arrows indicate the signal direction)

THERE IS NO SUBSTITUTE FOR —

LimiTorque®

PHILADELPHIA GEAR CORPORATION

KING OF PRUSSIA (SUBURBAN PHILADELPHIA), PA.

Offices in all Principal Cities

INDUSTRIAL GEARS & SPEED REDUCERS • LIMITORQUE VALVE CONTROLS • FLUID AGITATORS • FLEXIBLE COUPLINGS

Limitorque Corporation • King of Prussia, Penna.

input or output via punched cards or magnetic tape. It is also equipped with a conversion unit which converts voltage to acceptable levels.

U. S. Interior Department Discloses Import Changes

Proposed changes in the mandatory imports program, subject to Presidential proclamation, have been made public by the U.S. Department of the Interior. The department has requested industry comment on the three-part plan, which is designed to cut overall import levels by as much as 60,000 bpd in Districts 1-4.

Interior Under Secretary Bennett stated that "the proposal would result in a reduction of crude and unfinished oil imports east of the Rocky Mountains effective Jan. 1, 1961, depending upon issuance of a Presidential proclamation authorizing the proposed changes."

"While we cannot precisely predict the exact reduction because demand data and other pertinent information are not available," Bennett said, "the import level could be about 60,000 bpd below the level which would prevail if the proposal were not adopted."

Reduction in the overall import level of magnitude of 60,000 bpd would occur only if there were no increase in demand. Since demand is expected to increase, however, actual reduction from the present level is certain to be much less than 60,000 bpd, according to Interior Department reports.

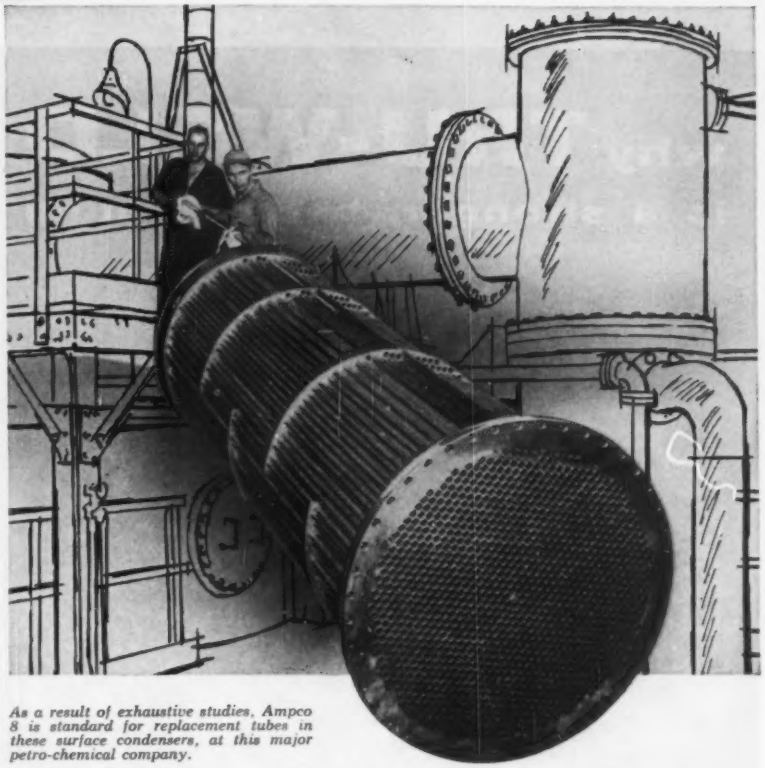
George S. Dunham, senior vice president, Socony Mobil Oil Co., views the import matter in this way, "Since our company and other similarly situated have been denied adequate residual fuel oil import quotas over the last 20 months, we strongly urge that the plan be put into effect not later than Jan. 1, 1961."

Jersey-Standard, Cepsa Appeal Spanish Decision

An appeal is being made to the Spanish government by Standard Oil Co. (New Jersey) and Compania Espanola de Petroleo, S.A., to the refusal to permit the two companies to form a $10-million petrochemical business in Spain.

A company spokesman said the appeal, filed with the Minister of Industry at Madrid, asked the government to reconsider the Jersey Standard-Cepsa proposal to build three petrochemical plants in Northern Spain. The joint application for necessary government permission was submitted to the minister last May and denied on September 2.

In appealing the decision, Cepsa and Jersey-Standard argued against the gov-



As a result of exhaustive studies, Ampco 8 is standard for replacement tubes in these surface condensers, at this major petro-chemical company.

Reduces corrosion-erosion of 5% sulfuric-acid vapors

On-job tests prove deterioration rate for Ampco metal tubing one-third lower than for copper

The cooling of overhead acid vapors discharging from an H_2SO_4 concentrator spelled trouble for one petrochemical company. After six months, the top ends of the copper tubes in surface condensers had deteriorated due to corrosion-erosion. It was decided to test other materials in this service.

In one 34-day test, specimens were placed at the entrance to the tubes. Results showed that Ampco 8 would give about 50% longer service than the original copper tubes.

A later 45-day test — with samples placed away from tube sheets to minimize erosion — showed Ampco 8 superior to other copper-base and stainless alloys.

The excellent heat-transfer rate and outstanding corrosion resistance of Ampco Tubing provide highest efficiency in many types of equipment. Write us concerning *your* problem.

Corrosion Rate — IPY	
...in 34-day high-velocity test:	
Copper	0.022
Ampco 8	0.015
Carpenter 20	0.056
...in 45-day corrosion test:	
Ampco 8	0.0046
Aluminum brass	0.009
Silicon bronze	0.018
Type 316 (high Mo)	0.020
Hastelloy B	0.0038
Allegheny	0.008
Nionel	0.0019

In both tests...
Temperature was 200°—270°
Acid concentration was 0-5% H_2SO_4
Data from Chemical Engineering, February, 1957

PI-36

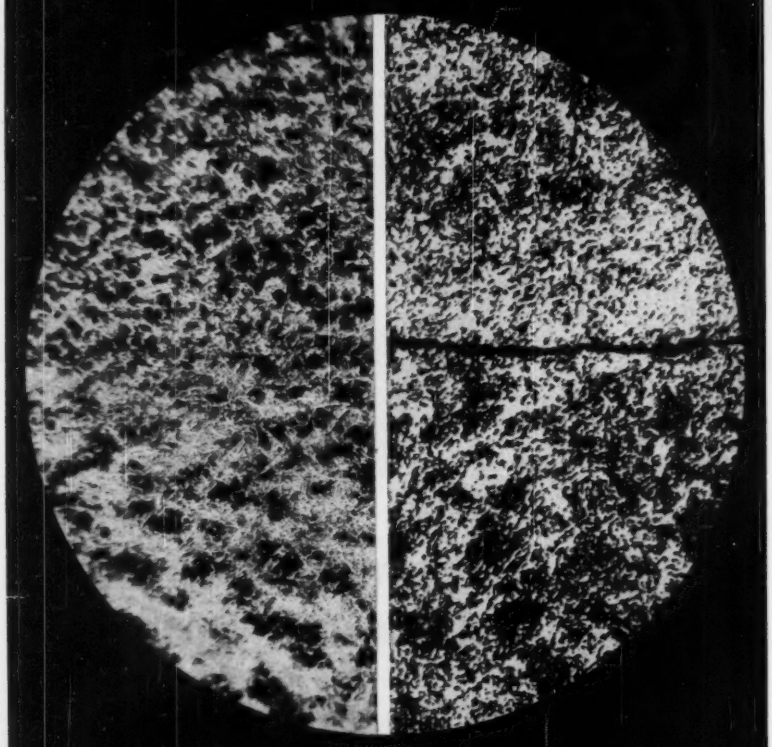
AMPCO

AMPCO THE METAL WITHOUT AN EQUAL

AMPCO METAL, INC., Dept. 381 K, Milwaukee 1, Wis.

West Coast Division: Huntington Park, Calif. • Southwest Division: Garland (Dallas County), Tex.

why TRU-WELD
is a stronger, better grating



photomicrograph of grating welds

This enlargement of the weld area in TRU-WELD grating shows how solidly the metals have joined. Cross bar and bearing bar have fused into a strong, moisture- and vibration-proof weld.

Enlargement of an incomplete weld area. Note the line of separation between bearing bar and cross bar. Heavy traffic and vibration can easily separate such a weld.

Tru-Weld grating is stronger because it is *made* that way. Its added strength comes from a manufacturing process that completely fuses the metal at cross bar-bearing bar joints and holds the bars to exact spacing. The result is grating that stands up under excessive vibration, heavy traffic or in areas where corrosive fumes and moisture are a problem. And Dravo Tru-Weld grating *costs no more.*

Complete estimating, layout and fabricating services are available. Immediate delivery from stocks maintained at nearby Joseph T. Ryerson Service Centers will help you meet exacting construction schedules.

For more information on this new, stronger grating, call the Dravo representative in your area, or write DRAVO CORPORATION, PITTSBURGH 25, PA.

DRAVO
CORPORATION

Happenings . . .

ernment's contention that their proposed facilities would duplicate those of competitive applicants recently approved in Madrid. With statistics, market studies and graphs, tracing the growth of petrochemical demand in Western Europe, they countered the minister's arguments that chemical plant expansion in Spain must await future demand. Presentations to various government ministers have pointed out that the Jersey-Cepsa project would attract other industries to Spain.

If approval of the Jersey-Standard-Cepsa application is obtained, the company spokesman said, the two firms will form a partnership to produce and market more than 24,000 tons of petrochemicals per year. Included would be raw materials for detergents, plastics and rubber for Spanish industry. Ultimate investment in the over-all petrochemical industry in Northern Spanish could reach $26 million, he added.

Sohio Uses Improved Process for Lubes

The thermal diffusion process used in World War II to make U^{235} for atom bombs has been improved for the manufacture of exceptional quality lubricants by researchers of The Standard Oil Co. (Ohio) at Cleveland. This report was made to the American Institute of Chemical Engineers at their National Meeting in Tulsa. Dr. Robert Grasselli, Standard-Ohio described a major advance in the design of thermal diffusion equipment which reduces the costs by 40 percent.

Dr. A. L. Jones of Sohio discovered some years ago that the best lubricant molecules are driven to the hot wall of a unit in which one wall is simply heated and the other cooled. Oils having viscosity index characteristics as high as 150 without the use of additives were produced. The new discovery utilizes a new principal in chemical engineering to reduce the capital costs for the units. A plant consisting of ten units, costing about $110,000 would be expected to yield between 1200 and 3300 gallons of high viscosity oil product per day.

The technique applies to many other mixtures of oil and of chemicals and is particularly attractive where heat is being exchanged for other purposes.

'Major Advance' in Missile Lubes Described

A chemical promising "a major advance" in lubrication for missiles and nuclear aircraft and submarines has been described by a Shell Development Co. scientist.

The product has kept bearings running smoothly for long periods at temperatures as high as 800° F under high doses of radiation. The chemical is one of a family called polyphenyl ethers. In simi-

For more data on advertised products, use Readers' Service Cards, last page.

sharp

AMERICAN BI-METAL THERMOMETERS make accurate temperature readings sharp and sure at all check points

American Dial Thermometers are also available in mercury, vapor pressure, and gas actuation . . . on-the-spot and distant reading types . . . in sizes, ranges and stem lengths to meet your most exacting requirements.

sensitive

Any way you look at an American Bi-Metal Thermometer, you see exact working temperatures.

The two-level "Maxivision®" dial eliminates parallax effects. Numerals are on the lower level. Graduations are on the outer raised ring dial which presents a sheared edge to the tip of the pointer and in the same plane. To make readability even more accurate, the glass and graduated dial are closely spaced.

American Bi-Metal Thermometers are made of weather-proof stainless steel. All joints are welded to solid unity, then polished smooth so corrosion won't build up and destroy the thermometer's usefulness. And, you don't have to discard this thermometer even if the glass is ever broken. The bayonet lock bezel makes replacement easy.

Learn about the high sustained accuracy and long service life built into American Bi-Metal Thermometers. Phone your nearby industrial supply distributor for help in selecting the right type for each temperature check point in your plant. Or write for Catalog 100A.

MAXWELL MANNING M&M & MOORE INC. TRADE MARK

AMERICAN INDUSTRIAL THERMOMETERS

A product of

MANNING, MAXWELL & MOORE, INC.

Gauge and Instrument Division • Stratford, Connecticut
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

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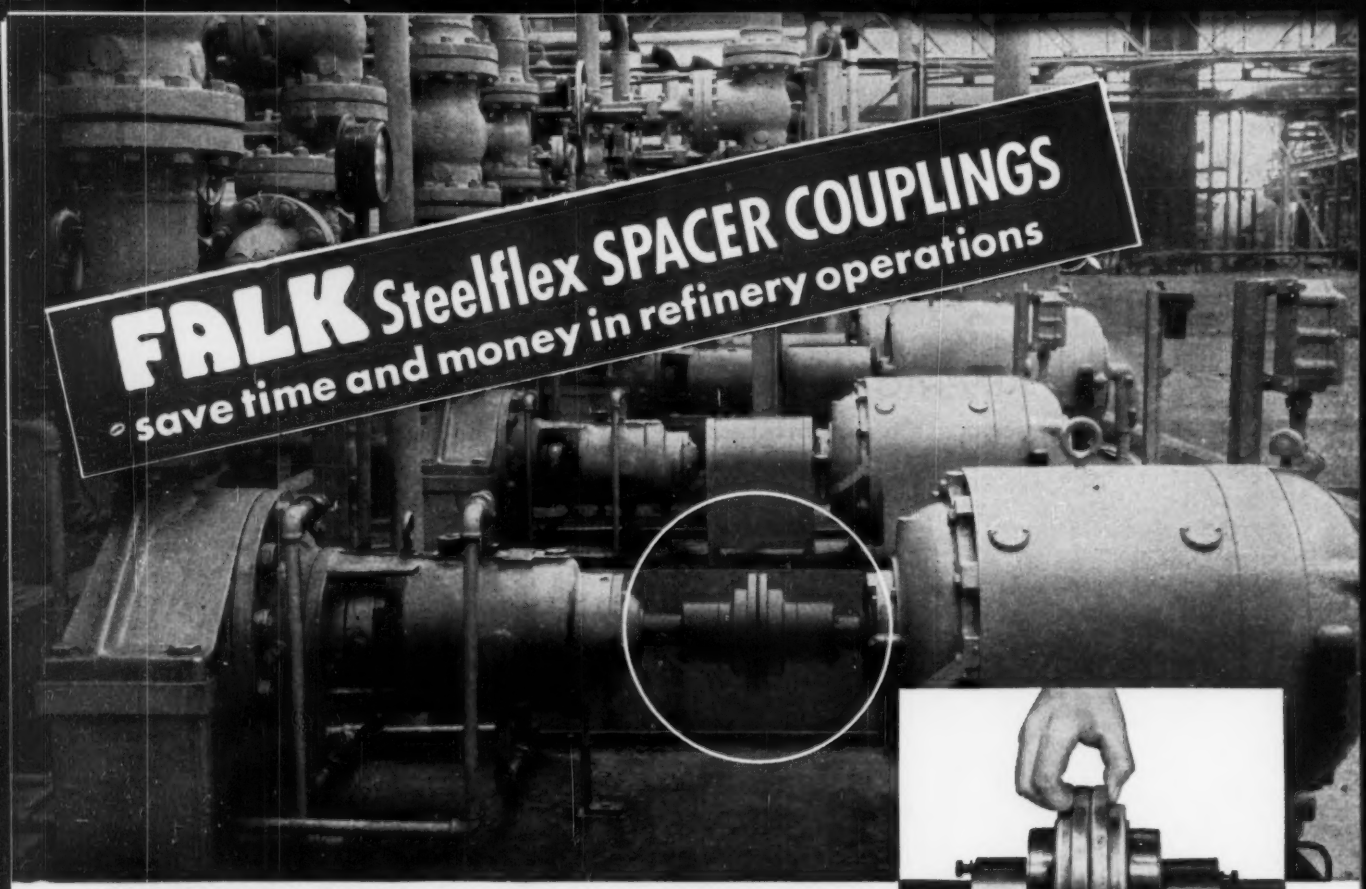


FALK and STEELFLEX are Registered Trademarks

Cut disconnect-reconnect time by as much as 50%

The FALK Spacer Coupling is specially designed for quick installation or removal *without disturbing the driving or driven unit.* This feature can save you up to 50% in disconnect-reconnect time when critical equipment—a process pump, for example—needs repair or replacement.

Here's another saving: with the FALK Spacer Coupling, you can quickly realign shafts *without the usual loss of operating temperature!*

And still another: you can remove or reinstall the FALK Spacer as a unit *without draining the lubricant.*

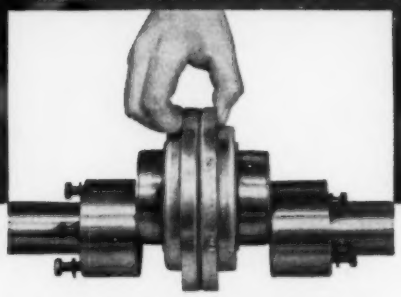
Because of its exclusive grid-groove Steelflex design, the FALK Spacer can accommodate residual misalignment—parallel, angular, or (most important) *both.* Also, it provides torsional resiliency that cushions shock and vibration. Thus it saves wear-and-tear on your connected equipment.

To prove these claims and enjoy these savings, install a FALK Spacer on one application—and see for yourself. Consult your FALK Representative or Authorized Distributor.

THE FALK CORPORATION, MILWAUKEE 1, WISCONSIN

MANUFACTURERS OF QUALITY GEAR DRIVES AND FLEXIBLE SHAFT COUPLINGS

Representatives and Distributors in many principal cities.

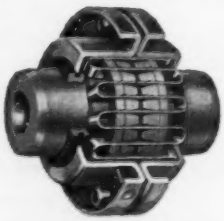


EASY AND QUICK TO INSTALL, DISCONNECT OR RECONNECT

First, mount shaft hubs to allow proper distance between hubs; then, align driving and driven units.

Second, compress Spacer to fit space between hubs and tighten cap screws to pull spacer hubs into the registered fit.

To disconnect, reverse the second step. No draining of lubricant necessary.



The heart of the FALK Spacer ...the basic Type F Steelflex

Write for Service Manual 4838

FALK

...a good name in industry

lar tests, conventional lubricants broke down at temperatures above 400° F.

The chemical's performance, called "greatly superior to that of conventional lubricants," was reported by J. B. Accinelli of Shell Development Co. before a joint meeting of the American Society of Mechanical Engineers and the American Society of Lubrication Engineers at the Statler Hilton Hotel, Boston.

He said the three main factors shortening the life of lubricants in missiles and nuclear vehicles are radiation, high temperature, and oxygen attack. The chemical proved itself under all three conditions. It kept bearings running smoothly for 100 hours. Under the same conditions, bearings lubricated with conventional oils began to fail after 17 hours.

Natural Gas, LPG See Increase Over July 1959

The daily average production of natural gas liquids in July was 7 percent above July 1959, according to the Bureau of Mines, U.S. Department of the Interior.

Average production of liquefied gases at refineries was 8 million gallons daily, 20 percent above July 1959. Ethane-ethylene production in July was 18 percent above July 1959. The daily average demand for liquefied gases for fuel and chemical uses decreased 4 percent from July 1959.

Stocks of liquefied gases, excluding ethane, totaled 1,180 million gallons, an increase of 156 million gallons during July 1960. Underground stocks of liquefied gases totaled 951 million gallons, 20 million gallons less than a year ago.

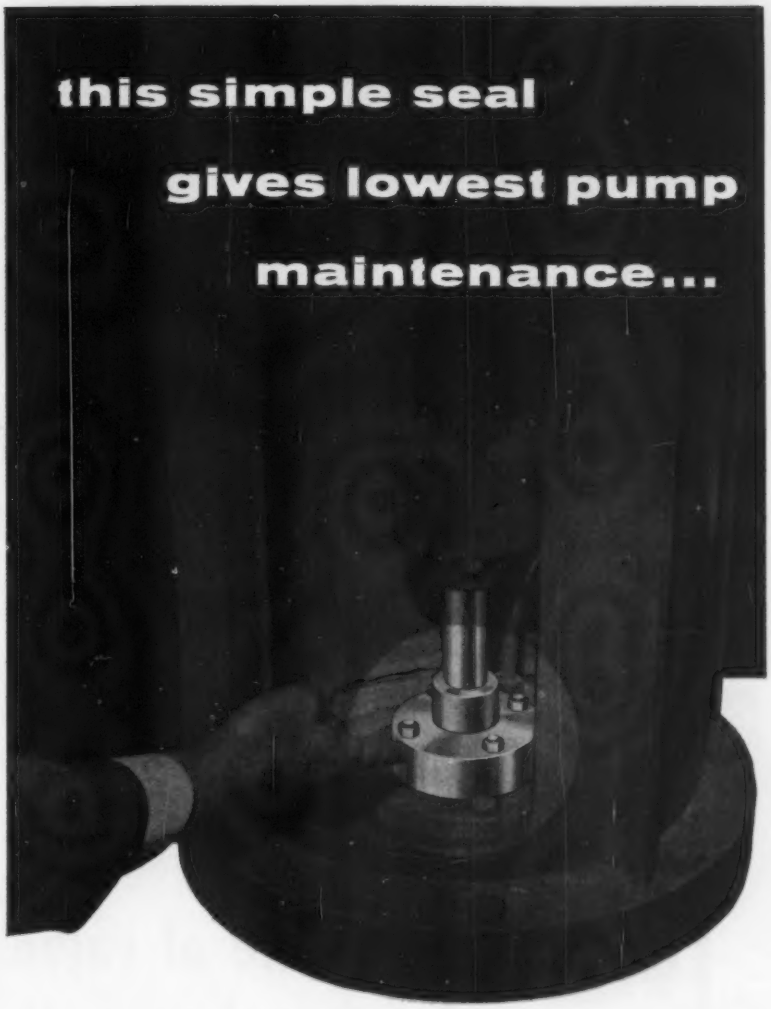
The daily average demand for natural gasoline was 12 million gallons, an increase of 1 percent from July 1959.

July Crude Takes Drop From June Figure

Production of crude petroleum in the United States averaged 6,860,000 bpd in July, a decrease of 79,000 bpd from the June average of 6,939,000 bpd, reports the Bureau of Mines, U.S. Department of the Interior. The decline of 70,000 bpd in Texas production during the month accounted for most of this decrease. Other significant changes in crude production in July were a 10,000 bpd or a 10 percent decrease in Utah and a 14,000 bpd increase in Wyoming.

The indicated demand for all crude oil in July increased 173,000 bpd, comprising an increase of 178,000 bpd for domestic crude and a decrease of 5,000 bpd for foreign crude. Total crude stocks, domestic and foreign, amounted to 242,745,000 barrels on July 31, compared with 257,301,000 at the end of June, a decrease of 14,556,000 barrels.

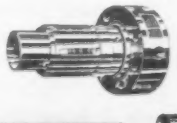
Total crude runs to stills in July aver-

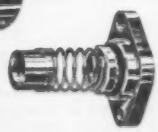


Save up to 66% of the time—expensive downtime—needed for installation or service of other mechanical seals used in plant process equipment.

The simple, effective Borg-Warner Type U Seal has no set screws—no close spring tension adjustments. It's fast and reliable.

For plants with a wide variety of pump service requirements, a minimum inventory of parts, and an easy change of gaskets adapts the Type U seal for service at temperatures of from —100 below zero to +650°F, and for pressures from 0 to 1000 psi.





Backed by Borg-Warner and proved in service, these dependable seals give complete safety, even in unattended stations.

Send for the latest Type U Seal engineering information—there's no obligation.

A PRODUCT OF B-W BORG-WARNER

Borg-Warner Mechanical Seals

P.O. Box 2017, Terminal Annex, Los Angeles 54, Calif.

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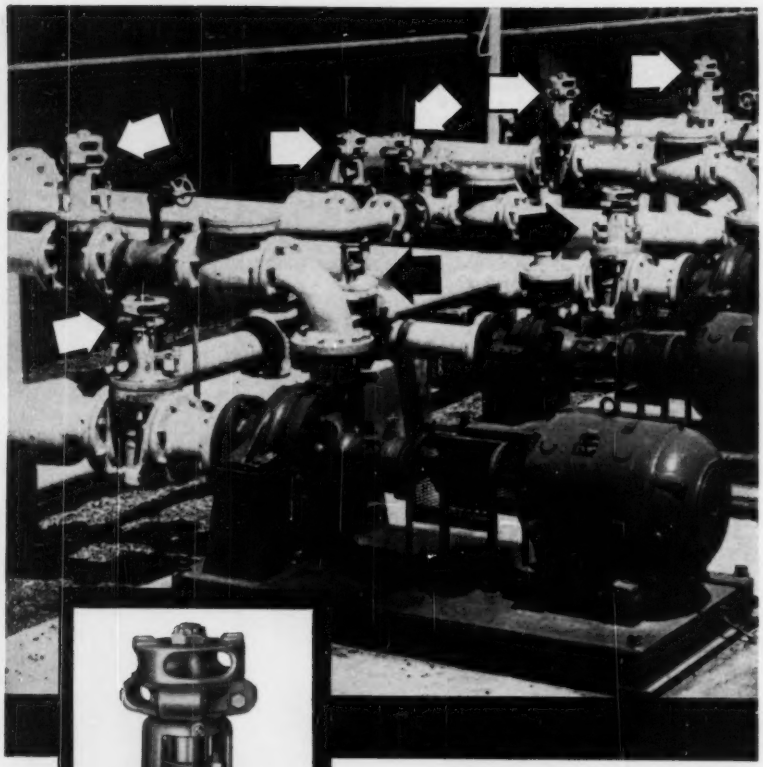

Eliminate the expense and trouble of valve lubrication with

HAMER PLUG VALVES

Hamer Plug Valves are unsurpassed for sure sealing, ease of operation and low maintenance cost. Being non-lubricated they not only eliminate the cost of lubrication but also prevent contamination of line product. The powerful plug adjusting nut acting as a screwjack is a positive means of raising and lowering the plug when operating the valve.

The plug and body seats are finished on special grinding machines and individually matched for precision fit, assuring smooth operation and perfect sealing.

Hamer Plug Valves are available in sizes 2" through 12" in working pressures to 600 lbs. W.O.G. Ask your Hamer Valve Specialist for complete specifications and applications of Hamer Plug Valves. Write for new catalog.

WECO

WELL EQUIPMENT MFG. CORP.
HOUSTON, TEXAS

Division of CHIKSAN COMPANY *a subsidiary of* FOOD MACHINERY AND CHEMICAL CORPORATION

HV-3-60

fmc

WECO UNIONS

CHIKSAN SWIVEL JOINTS

HAMER LINE BLIND VALVES

HAMER PLUG VALVES

Happenings . . .

aged 8,307,000 bpd, compared with 8,126,000 bpd in June. During July runs of domestic crude increased 183,000 bpd and runs of foreign crude decreased 2,000 bpd.

Stocks of refined products at the end of July amounted to 518,521,000 barrels, an increase of 25,688,000 barrels during the month and 5,182,000 barrels below the level of stocks reported for July 31, 1959. An increase of 21,870,000 barrels in distillate stocks during the month accounted for most of this rise.

Arab Petroleum Congress Adopts Four Resolutions

Four resolutions were recently adopted by the second Arab Petroleum Congress at Beirut, Lebanon, and Cairo, Egypt, was picked as the site of the 1961 meeting.

Resolutions adopted were:

- Congress support of the Arab countries' demands and their efforts which aim to improve the terms of oil concessions.
- Oil companies should have the consent of the governments of the Arab producing nations before reducing prices of crude oil and its products. The congress will uphold the governments in their refusal to recognize such reductions.
- Recommendation that Arab governments double their efforts to encourage technical, economic and legal research in oil affairs.
- Recommendation that the congress convene annually on the Monday of the third week of October and that the third congress be held in Cairo, Egypt.

Latin American Refining May Rise 50% in 10 Years

Oil refining in Latin American countries will increase by more than 50 percent within the next 10 years, and during that period about 17 new refineries will be built, according to E. W. Schnabel, licensing coordinator for Universal Oil Products Co.

Schnabel, who was speaking at a joint meeting of the American Institute of Chemical Engineers and the Instituto Mexicano de Inginieros Quimicos, in Mexico City, said that oil demand in Latin America had averaged an 8.6 percent yearly increase from 1949-59, roughly twice the U.S. rate. He predicted Latin American consumption would achieve 4.3 million bpd by 1970, compared with the current level of some 1.7 million bpd.

Refineries Come Prefabricated, Too

Not only houses come prefabricated these days, but so do refineries.

A 4,000-bpd-capacity, prefab refinery

For more data on advertised products, use Readers' Service Cards, last page.

IN A FIVE-MINUTE TELEPHONE CONVERSATION . . .

This gas processing specialist helped an operator save $3,000 a day

Recently, a West Texas natural gas processor called stating he was flaring sales gas due to high sulfur content caused by foaming in an ethanolamine system. The same antifoamants used successfully for some time were not effective. Subsequent questioning revealed that his gas stream was now at a higher temperature than the amine and a condensation of hydrocarbons resulted. On-the-phone-solution . . . raise the amine temperature to approximately 15° F. above that of the gas stream.

This, of course, was a simple one. More often Jefferson's experienced gas treating specialists will probe for pertinent data, request samples, and coordinate the solution of your problem through Jefferson's Austin Laboratories. Whether your problems be in desulfurization or dehydration . . . corrosion, foaming or contamination . . . Jefferson can draw on a vast fund of case experiences to help you avoid costly shutdowns, gas flaring or excessive solution losses.

For the *right* gas processing answers and chemicals . . . call Jefferson Chemical Company, Inc., 1121 Walker Avenue, P. O. Box 303, Houston 1, Texas.

Ethylene and Propylene Oxides, Glycols, Dichlorides, Carbonates
SURFONIC® Surface-Active Agents • Ethanolamines • Morpholine
N-Alkyl Morpholines • Polyethylene and Polypropylene Glycols
Piperazine • Piperazine Salts • Nonyl Phenol • Caustic Soda
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JEFFERSON CHEMICALS

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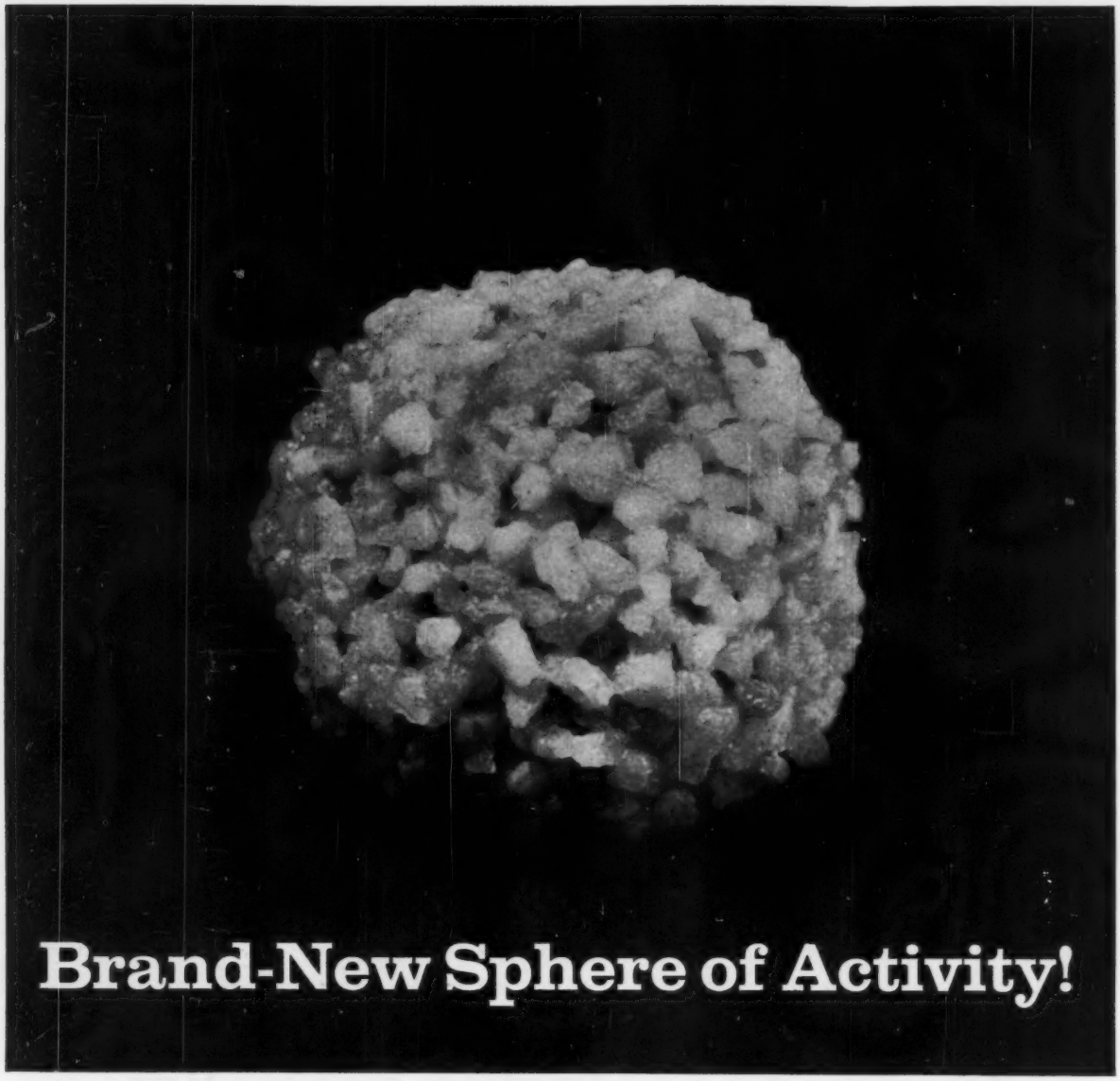


Brand-New Sphere of Activity!

Here is a MACROPORT* "A" aluminum oxide sphere — Norton Company's newest development in catalyst carriers shown enlarged. Note its extremely porous structure, specifically designed to promote *faster, more precisely controlled* gaseous reactions. Pores are much larger than those in other Norton catalyst carriers, permitting gases to enter and diffuse readily, yet providing sufficient restriction for optimum control.

MACROPORT "A" catalyst carriers are currently available as spheres, pellets, and aggregate of fused aluminum oxide in the same price ranges as standard Norton carriers. A research program is now underway in the Norton laboratories to develop MACROPORT carriers in other materials.

For better yields from *your* reactors and improved process economy, get complete details on Norton MACROPORT "A" carriers. Write NORTON COMPANY, Refractories Division, 470 New Bond Street, Worcester 6, Massachusetts.

TYPICAL PHYSICAL PROPERTIES

	MACROPORT "A" 5/16"-3/4" Spheres	Aggregate (3-5 Mesh)
Apparent Porosity %	44-48	40-44
H_2O Absorption %	22-26	18-22
App. Sp. Gravity g/cc	3.4-3.6	3.4-3.6
Bulk Density g/cc	1.8-2.0	2.0-2.2
Packing Density lbs./ft³	63-67	68-72
Pore Dia. Range	50-200 Microns	50-200 Microns

*Trademark

NORTON
REFRACTORIES
Engineered... Rx ...Prescribed

75 years of . . . Making better products . . . to make your products better

NORTON PRODUCTS: Abrasives • Grinding Wheels • Machine Tools • Refractories • Electro-Chemicals — BEHR-MANNING DIVISION: Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes

has been built by Lummus Co. to be set up in Guatemala. The plant, which cost about $4 million, is being erected on poured foundation pads in the jungle near Barrios. It will be called the Refinera Matias de Galvez.

The unit, which will produce all petroleum products except lubricating oil, was ordered by International Construction Associates, Inc.

The refinery was prefabricated because it may be moved easily, and because Guatemala does not have enough skilled labor to build a refinery.

Although this is not the first prefabricated refinery ever built, it is the largest. Lummus Co. built a similar one during World War II with a 1000-bpd capacity for the U.S. Navy.

The plant will be in operation by late January or early February.

'Catacarb' Process Already in Operation

The first commercial Catacarb plant for gas purification, a conversion from an existing hot carbonate unit for CO_2 removal, has been operating for several months. A substantial increase in gas treating capacity of the existing plant is claimed, and unit utility costs have been reduced. Alternately, with the same steam usage, an improved gas purity was obtained.

Also, the formation of a troublesome sludge has been eliminated by an improved corrosion inhibitor. Research led to non-poisonous catalysts, having a pronounced effect by catalysis of carbon dioxide absorption; hence, the name "Catacarb."

Several operating companies participated in the pilot and commercial plant demonstrations of the Catacarb Process, which is being licensed by A. G. Eickmeyer, Prairie Village, Kan.

Topics of AIChE Tulsa Meeting Discussed

A process for sweetening hydrocarbon liquids by removing sulfur compounds was described at the 43rd National Meeting of the American Institute of Chemical Engineers in September in Tulsa. The process has been proved in commercial application, four engineers said in a paper, "A Molecular Sieve Process for Sweetening Liquid Hydrocarbons."

In the process the liquid to be sweetened flows downward through a bed of molecular sieve pellets which adsorb the sulfur compounds and give off a liquid product passing the copper strip tests, the paper explained. The adsorbed sulfur compounds are removed periodically by a hot gas purge and the bed is then cooled with sour liquid feed and returned to operation.

Also discussed at the meeting was a

HARTZELL Reports . . . on dependable Water Cooling for Houston power station

Operating: 6 years

Performance: Trouble-free

Service: Low cost maintenance

These facts sum up the reliability and economy of Hartzell 14-foot Adjustable Pitch fan assemblies now operating at Houston Lighting and Power Company's Hiram O. Clarke station.

Of a total of 60 fans operating on this large induced draft tower that cools circulating water for power generation, a majority are Hartzell type "P," molded plastic model, which have provided trouble-free, low cost maintenance operation since 1954.

One important reason for the high quality of performance of Hartzell fans on this and thousands of other installations is the use of exclusive Hartzite plastic. This material far exceeds other blade materials in its ability to resist corrosion, abrasion and vibration.

Write for all the facts . . . or, better yet, let a Hartzell representative show you how a Hartzell fan will make "dollars and sense" in your cooling tower and heat exchanger operations.

HARTZELL PROPELLER FAN CO.

Engineering Offices in Principal Cities

Div. of Castle Hills Corp.

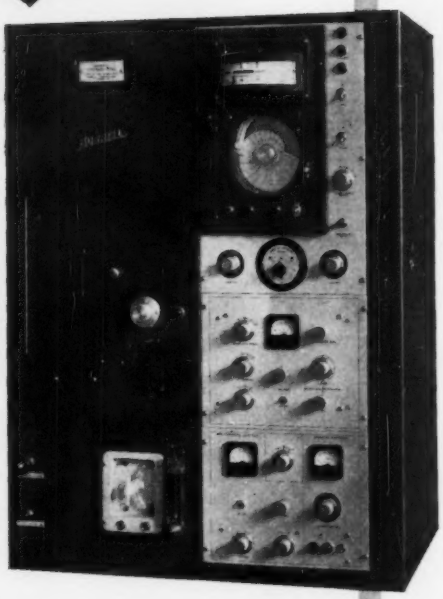
Piqua, Ohio

For more data on advertised products, use Readers' Service Cards, last page.

BURRELL "For Scientists Everywhere"

ADVANCED INSTRUMENTATION for GAS CHROMATOGRAPHY

New
BURRELL KROMO-TOG IONIZATION MODEL K-7



- Ultra-Sensitive, Completely Safe, Ionizing Detector
- Analyzes Fixed Gases and Both Organic and Inorganic Compounds
- Column Temperature Programming—Either Manual or Automatic

The new Burrell Kromo-Tog Model K-7 is designed for the most accurate chromatographic analysis possible. Its thermionic emission ionization detector has greatly increased sensitivity, speeds analysis and permits use of small diameter columns and smaller samples. It is the only method that will analyze both organic and inorganic compounds as well as fixed or permanent gases.

Superior standard equipment includes a gas sampler, column temperature indicator, automatic controller for constant or variable temperature operation, built-in flowmeter, and flash vaporizer. Potentiometer recorder, offered separately, mounts next to Model K-7 on laboratory bench or table top.

Request complete data—ask for Bulletin No. 841.

BURRELL CORPORATION
SCIENTIFIC INSTRUMENTS AND LABORATORY SUPPLIES
2223 Fifth Avenue, Pittsburgh 19, Pa.

Happenings . . .

"very promising" method for recovering petroleum products from natural gas. The method is a "new short cycle adsorption" process, "which makes it profitable to treat gas containing as little as 0.1 gallon of liquid per 1000 cubic feet." Four Phillips Petroleum Co. engineers reported on this process in a paper entitled, "Dynamic Adsorption of Isobutane and Isopentane on Silica Gel."

Successful oxidation of hydrocarbons on a commercial basis using 95 percent pure oxygen, rather than air, was explained in a report prepared by James M. Robertson of Celanese Chemical Co. The process is said to be "the only one which has reached the stage of successful commercial development and exploitation."

One paper presented at the meeting summarized the petrochemical picture in the states of Arizona, New Mexico, Texas, Oklahoma and Louisiana by stating, "The Southwest has the lion's share of raw materials needed by the petrochemical industry and new discoveries promise to make the supply more abundant than ever."

Methods for converting residues to products of greater value were discussed in two papers. Challenge of the problem was outlined by H. Beuther, J. B. McKinley and R. A. Flinn of the Gulf Research & Development Co. in a paper, "Recent Developments in the Technology of Residue Processing."

Reports were made telling how plastic pipes are helping to reduce the "staggering" $600-million annual piping loss caused by corrosion in the United States. Modern hydrogen fluoride alkylation units that resulted in lessened operating costs, improved product quality, shortened pay-out period and sharply reduced per-barrel investment requirements were also a topic of discussion at the meeting.

Sinclair Forms Processing, Computing Department

A special department has been formed by Sinclair Oil Corp. to coordinate the expanding electronic data processing and computing activities of its operating subsidiaries. The new Electronics Department will integrate individual electronic operations to serve over-all corporate needs at minimum cost. Dr. K. A. Smith is manager of the new department, and A. J. Piemonte is coordinator of data processing.

Amoco Head Sees Rosy Future for Gas Sales

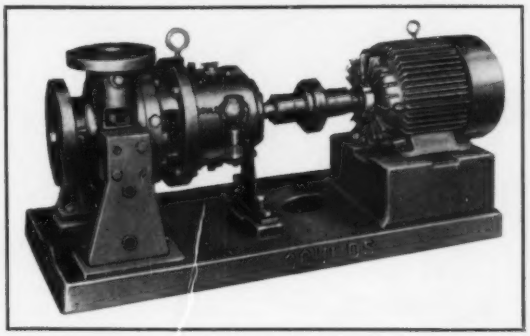
An oil company marketing executive has predicted that gasoline sales will continue to enjoy "a healthy growth rate" despite the trend toward compact cars.

For more data on advertised products, use Readers' Service Cards, last page.

THIS IS INTERMEDIATE-RANGE DESIGN

Robert Fornesi, Senior Application Engineer, Goulds Pumps, Inc.

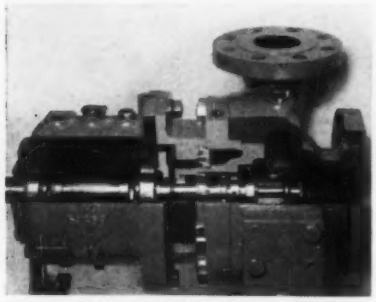
Changing requirements created this third dimension in process pump selection



Once upon a time you had to meet petroleum process applications with pumps in only these two ranges: (1) Light duty pumps to handle temperatures up to 200° or at most 300°. (2) Real heavy duty pumps for 200° to 800°. That's changed.

Here's why. Goulds product development group appraised the growing range requirements and services of petroleum process pumps. They found that 200° was no longer a realistic dividing line for process pump types. The need was for one pump which would handle all light duty applications and the growing number of intermediate applications as well.

Why should you have to buy a light duty pump with built-in temperature limitations when an intermediate-range pump could be built for almost the same price? Why should you pay for an 800° heavy duty pump to handle all the applications above 200° or 300°?



THIS DESIGN SOLVES HIGH TEMPERATURE SEAL PROBLEMS

Goulds designers felt they had the answer to both these questions in their plans for the Model 3775 line. This was not enough.

The design concept was verified by field research. The plans were rolled up from the drawing board and flown and shown all over the country. Plant superintendents and operating engineers saw them. They said yes.

They liked the rather obvious ideas that made INTERMEDIATE DESIGN POSSIBLE . . . the mechanical seal isolated in a seal chamber. This to allow for cooling of the liquid within the seal chamber. It made higher temperature handling with mechanical seals possible as it protected the seal. In similarly priced pumps the mechanical seal area behind the impeller is wide open. The hot pumpage is in constant contact with the seal. With the Model 3775 seals are not exposed to direct contact with hot pumpage. Cooler seals mean longer seal life.

COOLED CASING SUPPORT . . . A PLUS FEATURE

This was not enough. To be completely fit for INTERMEDIATE-RANGE (up to 650°) applications the Model 3775 had to have these features of costlier heavy duty pumps—cooled bearings and casing support.

Goulds Model 3775 has them all—water-cooled bearing housing and casing support as well as the seal chamber. This plus the choice of either internal or external flushing of the seal chamber. Single, double, balanced or unbalanced seals available to properly fit the application.

The pump is back pull-out type for easy maintenance. A spacer coupling allows you to remove the rotating parts without disturbing pipe connections or driver.

Built in accordance with API 610 specs, the fine mechanical features of this pump provide a husky line of pumps with maximum standardization and interchangeability of parts. Eleven sizes are built on the same bearing frame.

The Model 3775 is a horizontal center line mount with vertically split casings. Renewable casing wearing rings maintain proper clearance with impeller wearing rings. Leakage between suction and discharge chambers of the casing can be held to an absolute minimum.

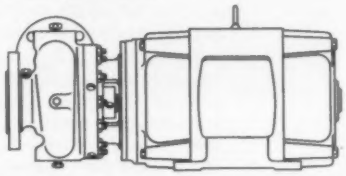
Talk over your process handling methods and problems with your Goulds engineer. He'll show you many more reasons why the INTERMEDIATE-RANGE 3775 is your best process pump choice for the majority of applications . . . *why it makes light duty pumps obsolete.* How it better fits the growing range of your process requirements.

AND AT LAST . . . A CLOSE-COUPLED PROCESS PUMP!

Goulds Model 3675 is the close-coupled version of the 3775. These units use the same liquid end as the frame mounts. The 3675 casing may be swiveled to four different discharge positions.

This integral pump-motor design provides the maximum in economy and compactness. Flexibility, too! One of our customers changed a process. A steel-case pump was required. Buy all new units? No, Goulds Model 3675 liquid ends fitted on the customer's present motors and provided the same rating. Only the casing was changed.

Get the complete story on these new pumps and all the others in the modern Goulds line. Send our factory the coupon below.



GOULDS PUMPS

GOULDS PUMPS, INC. Dept. PR-110, Seneca Falls, N.Y., U.S.A.

Send me a bulletin with complete application data on your INTERMEDIATE-RANGE DESIGN petroleum process pump.

Anything else? Please check.

- ☐ 1-stage centrifugal—Model 3405
- ☐ 2-stage centrifugal—Model 3305
- ☐ Steel case Pumps Bulletin

NAME _____ DEPT. OR TITLE _____

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BONDSTRAND®

An imaginative solution to your piping problems

From Missile Research...
A new product for process piping

- Twice as strong as steel
- 1/4 the weight of steel
- Inherently resistant to chemicals which attack stainless steel

Bondstrand is a corrosion-resistant, high strength, rigid pipe made of glass filaments bonded in chemically inert synthetic resins. It is capable of withstanding high pressure and the corrosive attack of many salt, acid, and alkaline solutions. The outside surface is equally resistant because the pipe is made entirely of corrosion-proof materials. No painting or maintenance is necessary.

Bondstrand's light weight and ease of assembly can save up to 50% of installation costs. Actual cost records of typical applications prove that the total installed cost averaged only 1.3 times that of carbon steel pipe. By eliminating the corrosion problem and down time for replacement or repair, Bondstrand saves many times its slightly higher initial cost.

Bondstrand is now available in sizes from 2" through 8" with all necessary couplings and fittings. Larger sizes available on special order.

Write for bulletin containing complete data, including physical properties, chemical resistance, flow rates, and other design information.

Amercoat® CORPORATION 126

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Happenings . . .

C. H. Coughlin, vice president, marketing, The American Oil Co., told members of the Alabama-Mississippi Oil Jobbers Association that there would be 16 million compact cars on the road by 1965.

Speaking at the association's convention in Biloxi, Miss., Coughlin said, however, that the trend toward smaller cars "in itself is not alarming" to oil marketers. "Forecasters say that in 1965, even with compacts, the industry will sell over 1.75 billion barrels of gasoline," Coughlin said. He added that the projected figure represents an increase of 14 percent over 1960 sales and only 3 percent below what it would be if there were no compacts.

Mobil Is Marketing New Additive in Britain

Tetramel, a new petrol additive which, it is claimed, gives a greater anti-knock quality than any other additive in use, is being marketed by Mobil Oil Co. in Great Britain.

Company officials disclosed that, due to the wide boiling range of petrol—from about 100 to 400° F—and the fact that petrol produced in catalytic cracking and catalytic reforming units has high anti-knock qualities in the light and heavy sections respectively of this range, the anti-knock quality of the fuel distributed through a car's inlet manifold containing, of course, medium components as well, may not be the same in each cylinder.

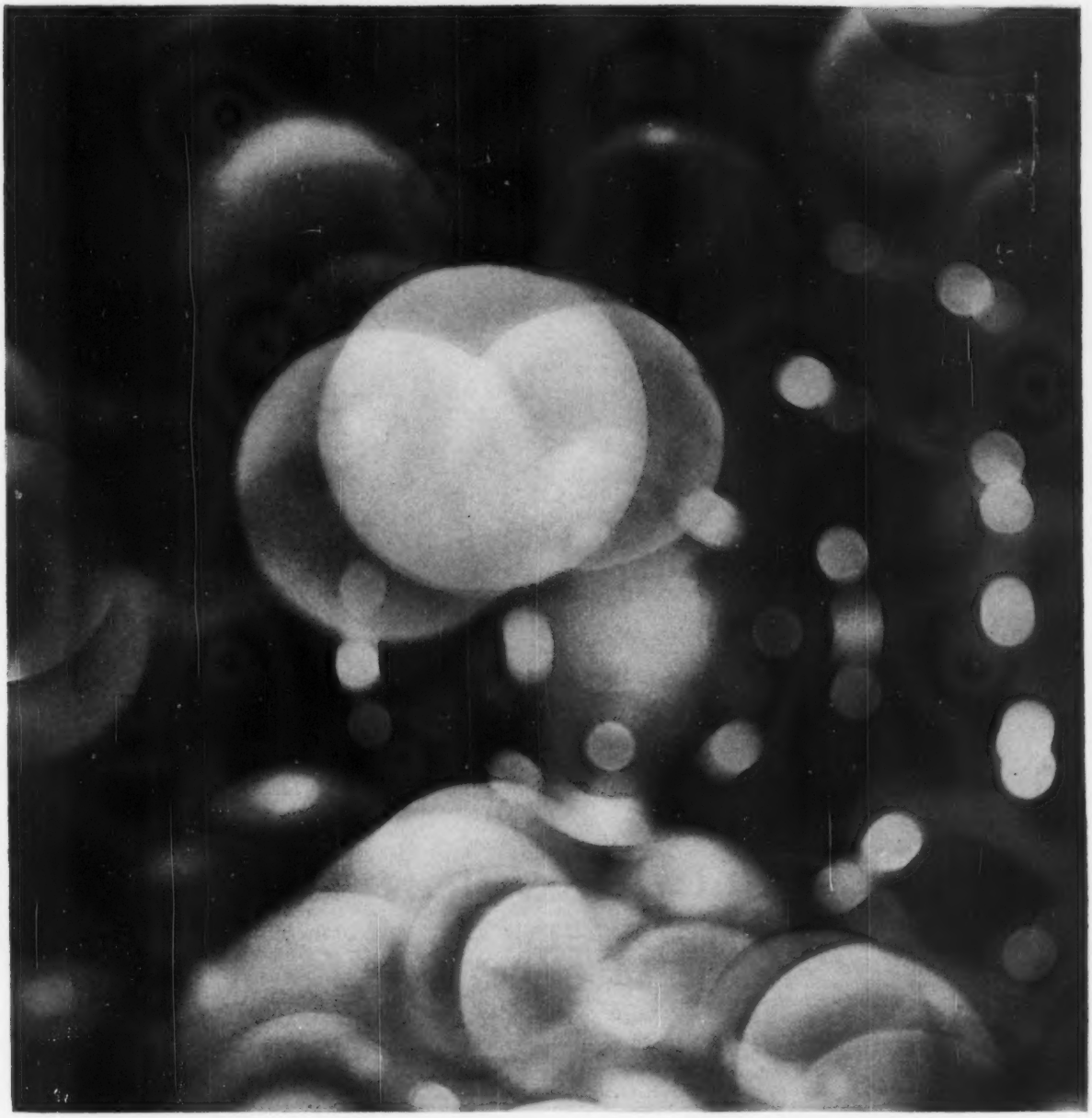
Tetramel has a boiling point of 230° F, practically in the middle of the petrol boiling range, and is thus claimed to ensure that the anti-knock quality of the fuel is the same for all cylinders.

Fuel Cell Research Begins at Battelle

A long-term research program to advance fuel-cell technology, described as "a major research effort being underwritten by some 25 companies", has just begun at Battelle Memorial Institute, Columbus, Ohio.

The program, presently on a five-year schedule, "will be fundamental in nature and is designed to complement existing government, industrial, and academic studies on fuel cell technology", according to Dr. John McCallum, project director. "Before the fuel cell's full potential can be realized as a source of power for automobiles, domestic heating and cooling, and industrial processes," he said, "there will have to be a number of inventions, innovations, and breakthroughs. Battelle, with its diversity of scientific disciplines, hopes to contribute to this process of discovery."

Much of the Battelle's research on the



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For finer products . . . let Alcoa add new dimension to your creative thinking!

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RETURN LINE CORROSION *Can* BE LICKED!

Drastic reduction of return line corrosion in an easy, effective and economical way has been the unanimous experience of hundreds of plants throughout the country using Bird-Archer's Amine Treatment.

A plant in New York State, generating approximately 500,000 lb. of steam a day, had a normal condensate pH value of 6.3 that resulted in almost constant piping replacements. Only 6 lb. per day of Bird-Archer's Amine Treatment cut maintenance costs to a new low by raising the pH value to the safe range of 8.0 to 8.5.

A plant in New England, generating 600,000 lb. of steam a day, did not have an open feedwater heater which would mechanically eliminate the exceedingly high CO_2 content of their makeup water, consequently, the pH value of their condensate was sometimes as low as 5.9. Less than 12 lb. of Amine Treatment a day raises the pH value of the condensate to 8.5, eliminates excessive corrosion.

After two years of experience with Amine Treatment a power plant in Massachusetts, making 250,000 lb. of steam a day, enthusiastically reports that they eliminate over 75% of their piping replacements through the use of only 2 or 3 lb. a day of Amine Treatment.

Return line corrosion has been licked at these plants. Let a Bird-Archer Service Engineer help you solve *your* corrosion problems.

Write for Bulletin CP100 and the name of the Bird-Archer Service Engineer nearest you.

BA-801

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Offices in Canada and Mexico

Happenings . . .

fuel cell will be aimed at obtaining a better understanding of the properties of materials required in a cell and developing materials which approach the ideal, according to Dr. McCallum.

One approach to improved materials for the fuel cell that Battelle will use is to study the internal electronic structure of alloys. From this study, scientists hope that they will be able to develop an alloy composition with unique electrical and electrochemical properties for cell electrodes.

Another approach to be employed in the Battelle program is the study of thin films of metals. Thickness of such films greatly affects their properties. A better knowledge of these properties may be a significant factor in the selection of the right combination of materials for more efficient fuel cells.

New Congress to Stress Depletion Issue, Says Gray

It has been predicted that the new U.S. Congress will put more stress on anti-oil legislation. Archie D. Gray, senior vice president, Gulf Oil Co., made the prediction at a meeting of the Mississippi-Alabama Division, Mid-Continent Oil & Gas Association. Gray said that over-all legislative matters will probably remain pretty much unchanged.

He anticipates the following to take place in the 1961 session and following sessions:

- Increased strength among those opposed to percentage depletion, particularly among legislators seeking reduction.
- Strong, and possible successful effort to block the new renewal of reciprocal trade agreement.
- Greater pressure by advocates of the so-called national fuels policy.
- Strong demand, both in Congress and many state houses, for additional taxes on gasoline.

Gray said that greater support of the consumer must be enlisted to help strengthen the efforts toward depletion.

UOP, Arvin Industries Join In Research Program

An agreement has been made between Universal Oil Products Co., Des Plaines, Ill., and Arvin Industries, Inc., Columbus, Ind., to exchange technical information and to cooperate in testing catalytic devices for purification of automotive exhaust gases.

Universal, a leading authority on catalysis, has developed both a catalyst and a catalytic muffler for reducing noxious exhaust emissions. Arvin, a major manufacturer and supplier of automotive parts, is actively engaged in development work in the same areas.

The cooperative effort is expected to accelerate certification, large-scale production and commercialization of effec-

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"We deliver too"

What's so special about the huge fractionating tower shown here? It is one more example of how Sun Ship builds and delivers heavy industrial equipment on barges or sea-going vessels, with careful attention to such requirements as safety and on-time schedule.

Whether it's a fractionating tower or key structural part for industry, transporting big items by water or by rail is strictly routine for Sun Ship, for we build and deliver what's needed in many fields. If you have a machinery or heavy equipment problem, write to us about it.

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tive and economical exhaust control devices. The agreement will enable either Arvin or Universal to use the technical information of the other in marketing its catalytic device, and will enable Arvin, if it so desires, to market its device using catalysts purchased from Universal.

Shell Firm Develops Low-Temperature Fuel Cell

Shell Research, Ltd., has come up with a low-temperature fuel cell that can generate from three to five times more power per unit volume than other similar cells under development. The announcement was made by Dr. C. G. Williams, head of the company's research center at Thornton, Cheshire, England.

Development work has been carried out using hydrogen as the fuel, but the cell has demonstrated its ability to use other fuels and further work will be done in this direction.

The cell can operate with either alkaline or acid electrolytes. When run on hydrogen and oxygen at a pressure of 3 psi, current densities of 70 amps per square foot can readily be obtained with both types of electrolyte at room temperature. If air is substituted for oxygen, there is little loss in performance. As the cell warms up to 60° C, the output is doubled. Power per cubic foot is 3 to 5 kw.

Three Smithco induced draft air cooled exchangers in the Houston plant of a world wide refiner.

All over the world engineers are turning to air as the solution of their heat transfer problems, even in areas where water is readily available. The reason? — AIR COOLING DOES THE JOB WITH THE SAME EFFICIENCY AS WATER, YET ELIMINATES THE NEED FOR COSTLY WATER TREATMENT, REQUIRES LESS MAINTENANCE AND PROVIDES A LONGER PERIOD BETWEEN "TURN AROUNDS".

Smithco, whose **only** business is air cooled heat exchangers, has pioneered many significant developments in this field. Prominent among these is the Smithco **Metalbond** Fintube. The Metalbond provides a continuous metallic path from the tube to the fin. This metallic bond assures highly efficient performance even at the elevated temperatures encountered in refinery and chemical services. It also eliminates the possibility of external corrosion of the tube.

A SMITHCO AIR COOLED EXCHANGER MAY BE THE ANSWER TO SAVING COOLING DOLLARS IN YOUR EXISTING PLANT.

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Shell Head Cites Reasons For Slow Demand Rise in '61

Domestic demand for petroleum in 1961 will increase at even a slower rate than the 3 percent rise in 1959, according to Monroe Spaght, new president of Shell Oil Co. He bases this statement on the impact of compact cars, softening of the general business picture and the fact that natural gas is gaining more of the heating oil market.

Spaght doubts that any material changes in the mandatory imports program will occur in the near future. He believes that the pressures from foreign oil developed with United States' capital and domestic producers have balanced the imports program for the time being.

November Crude Demand At Almost 7 Million Bpd

Domestic crude demand for November has been forecast at 6,925,000 bpd by the Bureau of Mines, U. S. Department of the Interior. This estimate includes a total gasoline demand of 4,110,000 bpd.

Crude runs to stills in September were 8,028,000 bpd, including foreign runs of 7,910,000 bpd. Demand for crude in September amounted to 7,010,000 bpd.

The bureau reports that total demand for crude and products in the third quarter of 1960 will show little if any increase over the same period in 1959.

IPAA Chief Foresees Demand Needs for 1960's

In order to meet the demands of the coming decade and provide adequate reserves in the event of national emergency, domestic oil producers must find and develop 45 million barrels of petroleum liquids within the next 10 years. This is a report Alvin C. Hope, president of the Independent Petroleum Association of America, made at a meeting of the Independent Oilmen and Landowners Association of North Dakota.

Hope also defended a 27.5 percent depletion provision.

AIChE Exposition Scheduled in New Orleans

More than 21 percent of the exhibit space in the nation's first AIChE Petrochemical and Refining Exposition was reserved within the first two weeks after the space was made available. The exposition is scheduled for February 26 through March 1, 1961, in the Municipal Auditorium in New Orleans.

The event will be the first exposition

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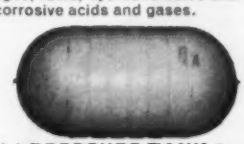
STAINLESS & CARBON STEEL TANKS
(GOVERNMENT SURPLUS BARGAINS)

Steel tanks for the handling, storage and transportation of gases, beverages, fuels, hydraulic fluids and other liquids. Stainless steel tanks for corrosive acids and gases.



J-1 PRESSURE TANK Stainless steel, surplus aircraft oxygen tank. 48" long, 24" dia. Rated for 400 P.S.I. working pressure, 18,000 cu. in. vol., 77.9 gal. capacity. ¼" pipe thread fitting at each end. New condition. Shipping weight 247 lbs. F.O.B. Chicago.
No. AH832 ..... $99.50

G-1 TANK Stainless steel. Capacity 2100 cu. in. (9 gals.) 450 P.S.I. ¼" pipe thread port at each end. 24" long, 12" dia. Shipping weight 19 lbs. F.O.B. Chicago. (Two for $27.00.)
No. AH63 Each $14.95

NON-SHATTERABLE CO_2 CYLINDER This type of pressure bottle was used by the Armed Forces for inflating life rafts. 18¼" long, 3¾" dia. Has ⅛" pipe thread opening at one end. Capacity 2.98 lbs. of CO_2—at 1800 P.S.I. Shipping weight 10 lbs. F.O.B. Chicago.
No. AH303 ..... $2.50

FREON TANK Capacity 22 oz. of Freon F22, 6 cc Methyl Alcohol. 18¼" long, 2" dia. ¾" pipe thread opening at one end. Equipped with brass valve. Shipping weight 3 lbs. F.O.B. Chicago. (Six for $8.00).
No. AH834 Each $1.50

D-2 AIR TANK Carbon steel. Capacity 500 cu. in. (approx. 2 gals.) 450 P.S.I. ¼" pipe thread port at each end. 24" long, 6" dia. Postpaid. (Two for $8.50).
No. AH391 Each $4.95

CORNELIUS HIGH PRESSURE (1500-2000 P.S.I.) AIR COMPRESSOR Three cylinder, 3-stage compressor, complete with 27 volt, D.C. 20 amp. motor, with fan. Rated 1500 P.S.I. continuous duty, 2000 P.S.I. intermittent. Pressure switch in base. As released by Air Force, in used, serviceable condition. Covered by our 30 day GUARANTEE. 11½" long, 7" high, 9" wide. Shipping weight 12 lbs. F.O.B. Chicago. Limited quantity.
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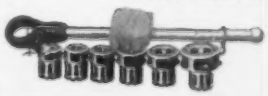

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Enclosed Ratchet Type
For pipe—⅛" to 1"—0-R
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30 COMPANIES

are saving money with Airlift TCC

Construction costs on Socony Mobil's Airlift Thermofor Catalytic Cracking units have been cut almost in half during the past ten years—a result of continuing Mobil research.

Operating costs have also been reduced. Three years ago Mobil introduced the Durabead catalyst, opening new money-saving horizons in TCC operation. Today's improved Heavy Durabead catalyst brings still greater economies.

Around the world, 51 Airlift TCC units are turning oil into money for 30 companies. Thirty-five of these units are operated under license from Socony Mobil by the 29 companies listed above. Two more units are now under construction, in Mexico and the Philippines. Mobil, itself, brings the company total to 30. Mobil has installed 16 Airlift TCC's in its own refineries in the United States and Europe.

For any refiner interested in the TCC, Mobil will help work out the best processing procedures and cracking yield patterns for a given crude. Address inquiries to Process Promotion Department, Socony Mobil Oil Company, Inc., 150 East 42nd Street, New York 17, N. Y.

SOCONY MOBIL OIL COMPANY, INC.

Leader in Refining Research

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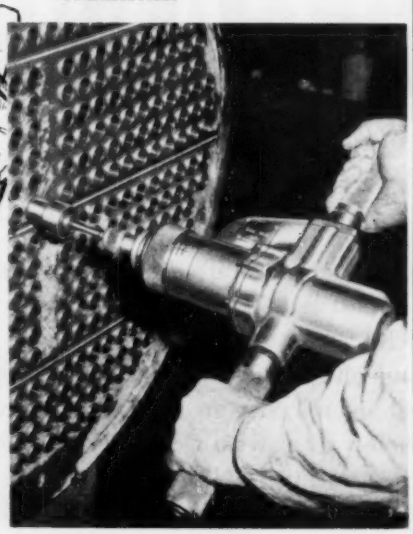
AIRETOOL stands up under torture

Yes sir! You can depend on Airetool for speed, accuracy and economy in tube maintenance

Airetool pneumatic tools—cleaners, drills, brushes and motors—are designed to meet the specific needs of refiners for efficient, low-cost tube maintenance and to do the job under the most difficult conditions.



For example, the AIRETROL Tube Expansion Control, illustrated at right, rolls up to 12 tubes a minute within .001 inch accuracy; maintenance costs drop and expensive tube failures are reduced. Labor costs are cut, too, because Airetrol's rugged, lightweight construction makes one-man operation easy.

And, one man can remove the hardest deposits and clean completely plugged tubes with Airetool's CC-475 Condenser Cleaner. The built-in flushing system keeps the drill cool and the cuttings washed away.

CC-475 CLEANER

If you're plagued by high tube maintenance costs, investigate the economies of Airetool tube equipment; it puts you on stream sooner and keeps you there longer. For full information write to:

BRANCH OFFICES: New York, Chicago, Tulsa, Philadelphia, Houston, Baton Rouge.
Representatives in principal cities of U.S.A., Canada, Mexico, South America, England, Europe, Puerto Rico, Italy, Japan, Hawaii.
CANADIAN PLANT: Brantford, Ontario.
EUROPEAN PLANT: Vlaardingen, The Netherlands.

AIRETOOL
MANUFACTURING COMPANY
SPRINGFIELD, OHIO

More than 30 years' experience in pneumatic tools

Happenings . . .

and conference sponsored by AIChE devoted solely to technological and research problems of the combined petrochemical and petroleum refining industries.

Sinclair Shuts Down Three Units at Corpus Christi

Sinclair Refining Company is revising its operations at its Corpus Christi plant. The revised plan of operations necessitates the shutting down of three main processing units.

The company stated that these units have been in operation for many years and have reached a stage where they can no longer be operated efficiently or economically. According to the company, lengthy consideration was given to the possibility of replacing these units with modern facilities, but it was determined that this would have required a large capital expenditure, which prevailing overall economics would not warrant.

Gulf Oil Sets Up Houston Services Office

A Domestic Services Department is being established by Gulf Oil Co. in Houston, Texas. The department will be in charge of advisory and service elements for domestic operations, including data processing, employe relations, insurance, law, public relations, purchasing, tax, treasury and Houston headquarters office services. K. E. Rotegard has been named manager of the department.

Stan-Cal Forms Company To Handle Chemical Business

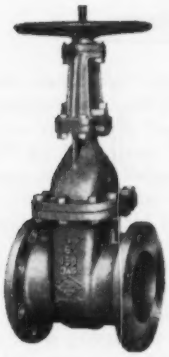
All of Standard Oil Co. of California's worldwide industrial and agricultural chemical activities have been grouped into one subsidiary.

The new organization, California Chemical Co., will coordinate and manage the manufacturing and marketing affairs previously handled by California Spray-Chemical Corp. and Oronite Chemical Co., and all of Standard's foreign chemical affiliations and marketing offices.

Calspray and Oronite become the Ortho and Oronite divisions of California Chemical Co.

Oil Head Sees No Gas Substitute in Near Future

An oil company president states it will be many years before new developments such as fuel cells supplant gasoline as the basic automotive fuel. L. W. Moore, president of the American Oil Co., told



In this **Split Wedge Gate**

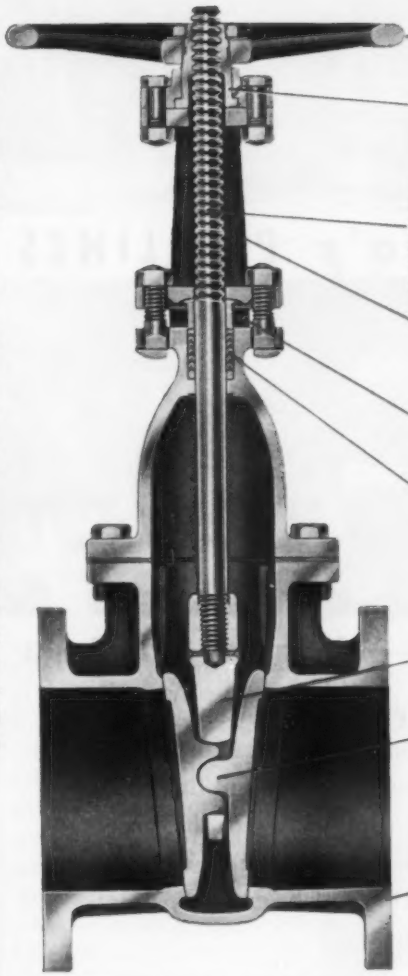
you can see why it pays to

Specify JENKINS for STAINLESS STEEL Valves, too

This picture shows the many points of excellence in the design and construction of Jenkins Fig. 1327 Split Wedge Stainless Steel Gate Valves. Compare them with any valve you know. You'll conclude that it's hard to beat Jenkins at making valves, no matter what the material.

But no picture can show the quality of the castings . . . the precision machining . . . the rigid inspection and testing that have gone into this valve. All of these are as important as design and metal alloys in assuring long, dependable, economical valve service. And, all of them are up to the peak standards for which Jenkins has been known for almost a century.

SEND FOR NEW CATALOG of Jenkins Stainless Steel Valves. You'll find in it the patterns you want, in a choice of alloys that satisfy the requirements of practically all corrosive services. Also, you'll see that these Jenkins valves meet valve industry specifications and the high standards established by the leading users of stainless steel valves. Jenkins Bros., 100 Park Avenue, New York 17.



WHEEL of high strength malleable iron designed for firm grip and easy operation.

YOKE BUSHING, easily renewable. Made of bronze, for ideal thread engagement with stainless steel spindle, to prevent seizing or galling of spindle threads. Bushing of stainless steel is optional.

SPINDLE has long thread bearing surfaces with correct lead for easy, tight closing. Screws into wedge carrier, then secured by a stainless steel pin.

YOKE BONNET has liberal space between yoke arms for easy access to packing box. Precision machined flange face assures uniform contact with gasket for a tight body-bonnet joint.

GLAND consists of two pieces — gland flange and gland follower — eliminates binding of follower in case gland bolts are tightened unevenly.

PACKING of Chevron-type Teflon in large packing box prevents leakage. Only a minimum load is required on gland, extending service life of packing.

WEDGE CARRIER connects wedge to spindle and raises or lowers it. Husky in size to stand any operating strains.

SPLIT WEDGE is the ball-and-socket design which automatically adjusts to the tapered seating surfaces for positive shutoff. The discs, revolving freely in the wedge carrier, produce a self-cleaning action on seating surfaces and reduce possibility of galling and seizing.

BODY —Through-port design for full, free flow. Ample wall thickness and good design provide extra strength to withstand stresses. End flanges conform to M.S.S. specs.

JENKINS

LOOK FOR THE JENKINS DIAMOND

VALVES

Sold Through Leading Distributors Everywhere

JENKINS BROS., 100 Park Avenue, New York 17, N. Y.

☐ Send the new stainless steel valve catalog

☐ Have a representative call on me

NAME & TITLE.....

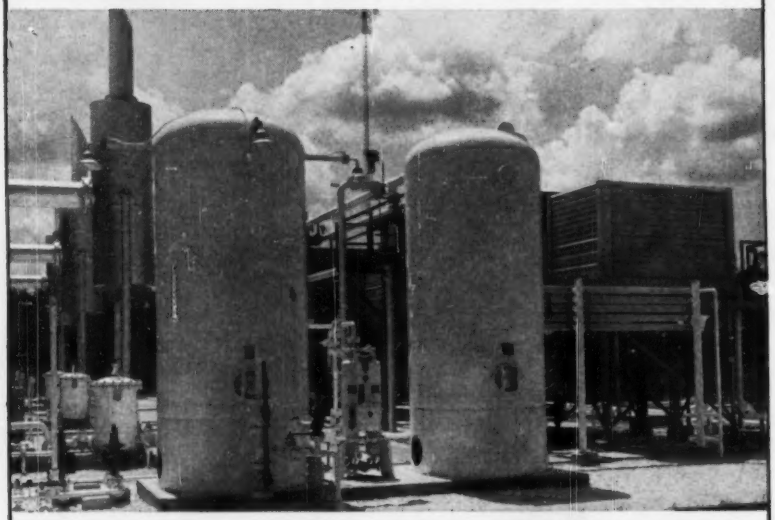
COMPANY.....

ADDRESS.....

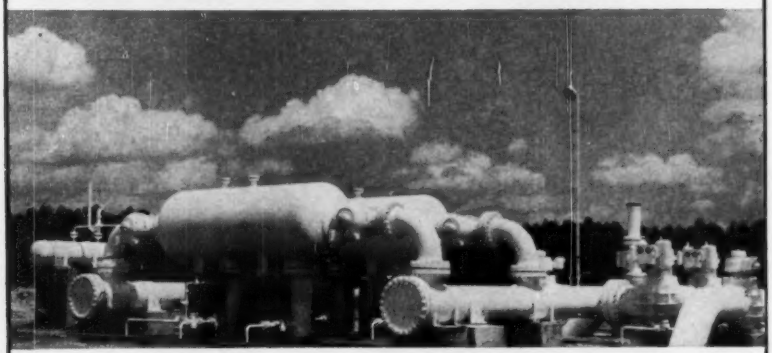
For more data on advertised products, use Readers' Service Cards, last page.

FLINT STEEL

PRESSURE VESSELS



Dot America's PIPELINES



Scrubbers—Snubbers—Air Tanks—Drip Tanks

These and many other processing and storage units for Natural Gas Pipelines are fabricated by Flint. More than forty-five years of heavy and light plate fabrication experience, combined with the largest and most modern plate manufacturing facilities in the Southwest enables Flint to fabricate to specifications on time.

SPECIALISTS IN STEEL FOR INDUSTRY

Write for booklet describing Flint's new steel fabricating facilities.

FLINT STEEL

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TULSA 1, OKLAHOMA

STEEL PLATE FABRICATORS ASSOCIATION

Happenings . . .

New York state oil jobbers that he could not "predict what revolutionary changes transportation technology will bring in the future," but he added, "I think it's fairly reasonable to suppose that for the foreseeable future gasoline will be the predominant fuel for the internal combustion engine."

In an address before the Empire State Petroleum Association, Moore said there is some validity to published statements that the service station is a basically unpopular institution, and said that "the successful marketer is going to be one who recognizes this basic truth and runs his business accordingly."

Socony Mobil Gets Electronic Computer

A lightning-fast, $3-million electronic computer has been installed by Socony Mobil Oil Co., Inc. It will be the ninth computer to be operated by the company around the United States and overseas.

The latest machine is reported by International Business Machines Corp. to be the most powerful transistorized electronic unit yet installed. Technicians set it up at Socony Mobil's electronic computer center, New York.

- Changing Times -

Domestic crude that will be consumed or exported in November will reach 6,925,000 bpd, compared with 6,785,000 bpd forecast for October, according to a Bureau of Mines estimate.

U.S. Military spends $1,092,691,000 for fiscal year 1960 on petroleum products and petroleum service contracts, Military Petroleum Supply Agency reports.

Italy enters pact with Russia to buy about 12 million tons of Soviet Union oil in exchange for 240,000 tons of steel tubes, oil pipe line equipment and 50,000 tons of synthetic rubber.

West Germany consumed 4.18 million tons of fuel in the first half of 1960, West German Federal Bureau of Statistics discloses. This total is a gain of 39.6 percent from the like 1959 period.

Monterey Oil Co. will sell all business and assets to Humble Oil & Refining Co. Monterey's principal properties are in California and Texas. The company also has production in Wyoming, Louisiana and New Mexico.

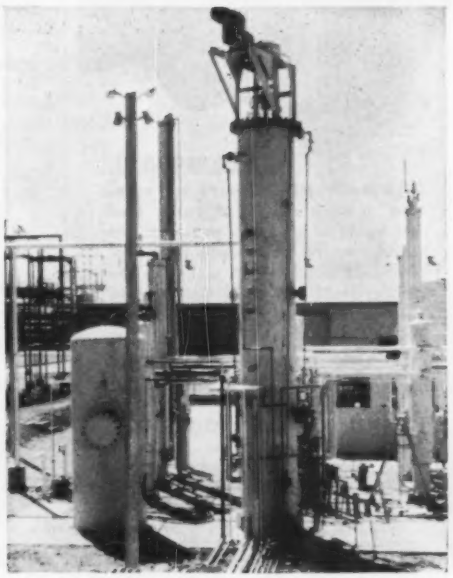
Continued on Page 353

13 COOPERATING COMPANIES* SELECT GENERAL AMERICAN RDC COLUMN FOR PROTOTYPE PLANT

Lignite low temperature tar is a relatively new and unknown raw material. To determine its potential value, a cooperative research program was started by 13 companies in 1954 at the Battelle Memorial Institute.

One of the important developments has been a solvent extraction process . . . a countercurrent extraction of this tar with 75% methanol—25% water and commercial hexane . . . using the RDC column. The development appeared so promising that a prototype plant was constructed at Alcoa's Rockdale Works by Texas Power & Light Company incorporating a General American RDC pilot column. *Only* the RDC column combines all these advantages: High volumetric efficiency, high throughput capacity, elimination of interstage settling, flexibility for changing feed conditions, lower power requirements, simple construction, tolerance for solids.

For any applications dealing with liquid-liquid, liquid-solid, liquid-slurry extraction . . . why not get full information on a General American RDC column? (Write for Bulletin #T-1159) Remember, *it pays to plan with General American.*



Process Equipment Division—Turbo-Mixers
GENERAL AMERICAN TRANSPORTATION CORPORATION
135 South LaSalle Street
Chicago 3, Illinois
Offices in principal cities

TURBO-MIXER GENERAL AMERICAN TRADE MARK

**Names on request*
EXCLUSIVE RDC LICENSEE IN THE PROCESS INDUSTRY

For more data on advertised products, use Readers' Service Cards, last page.

SKINNER-SEAL
PIPE JOINT CLAMP STOPS LEAKS
at joint where pipe is screwed into fitting

SKINNER-SEAL
PIPE JOINT CLAMP stops leaks at joints where pipe is screwed into fitting. Any temperature—any pressure up to 2,000 pounds. Saves the cost of tearing out and renewing leaky fittings. Prevents shutdowns. In stock at most oil supply stores.

SKINNER-SEAL
EMERGENCY PIPE CLAMPS for safe, sure, lasting repair of splits and rust holes in pipe. No pressure too high. Anyone can apply in a few moments. Made in all sizes, ½" to 12" for steel and C.I. pipe. Stocked by practically all oil supply stores.

Complete line of Repair Clamps. Send for Catalog 54!

M. B. SKINNER CO.
SOUTH BEND 21, INDIANA

Meetings Calendar

Nov.	
–18	**Natural Gasoline Association of America,** Panhandle-Plains Regional Meeting, Herring Hotel, Amarillo, Texas.
–18	**Society of Plastics Engineers,** Regional Technical Conference, Essex House, Newark, N.J.
20–22	**Fluid Controls Institute,** Fall Meeting, Drake Hotel, Chicago.
21–22	**American Institute of Mechanical Engineers,** Gulf Coast Section Society of Petroleum Engineers, Formation Evaluation Symposium, University of Houston, Houston, Texas.
27–Dec. 2	**American Society of Mechanical Engineers,** Annual Meeting, Statler Hilton Hotel, New York.
29–30	**Western Petroleum Refiners' Association,** Computer Conference, Hotel Tulsa, Tulsa, Okla.
Dec.	
4– 7	**American Institute of Chemical Engineers,** Meeting, Hotel Statler, Washington.
12–14	**U.S. Public Health Service,** National Conference on Water Pollution, Sheraton Park Hotel, Washington, D.C.
Jan. 1961	
16–19	**Instrument Society of America,** Conference & Exhibit, Winter Instrument-Automation, Sheraton-Jefferson Hotel, Kiel Auditorium, St. Louis, Mo.
–20	**NGAA,** Gulf Coast Regional Meeting, Robert Driscoll Hotel, Corpus Christi, Texas.
23–26	**Plant Maintenance & Engineering Show,** Conference, International Amphitheatre, Chicago.
23–Feb. 2	**Engineering and Management Course,** University of California, Los Angeles, Calif.
24–27	**SPE,** Annual Technical Conference, Shoreham Hotel, Washington, D.C.
Feb.	
7– 8	**Advanced Petroleum Engineer Seminar,** University of Oklahoma, Norman, Okla.
13–15	**American Industrial Writing Institute,** Western Industrial Writing Institute, Los Angeles Statler-Hilton Hotel, Los Angeles, Calif.
–24	**NGAA,** South Louisiana Regional Meeting, Lafayette Petroleum Club, Lafayette, La.
26–Mar. 1	**AIChE,** Petrochemical and Refining Exposition, Municipal Auditorium, New Orleans, La.
Mar.	
–11	**AIChE, American Chemical Society,** Joint Technical Meeting, Lamar State College, Beaumont, Texas.
13–17	**NACE,** Annual Meeting & Corrosion Show, Hotel Statler, Buffalo, N.Y.
15–17	**NGAA,** Annual Convention, The Baker Hotel, Dallas, Texas.
21–30	**American Chemical Society,** National Meeting, St. Louis, Mo.
27–31	**ISA,** Symposium on Temperature—Its Measurement and Control in Science and Industry, Veterans' Memorial Auditorium, Columbus, Ohio.
28–29	**Gas Conditioning Course,** University of Oklahoma, Norman, Okla.
April	
10–14	**Safety Engineering Course,** University of Oklahoma, Norman, Okla.
17–19	**ISA,** National Symposium on Instrumental Methods of Analysis, Shamrock-Hilton Hotel, Houston, Texas.
18–20	**American Welding Society,** Meeting and Show, Commodore Hotel, New York.
18–20	**Gas Measurement Short Course,** University of Oklahoma, Norman, Okla.
20–21	**AIME,** Society of Petroleum Engineers, Gas Technology Symposium, Tyler, Texas.
–28	**NGAA,** Oklahoma Regional Meeting, Lake Murray Lodge, Ardmore, Okla.
May	
8–11	**American Petroleum Institute,** Division of Refining, Midyear Meeting, Rice Hotel, Houston, Texas.
8–12	**API,** Accident Prevention and Fire Protection Meetings, Statler-Hilton Hotel, Detroit.
–19	**NGAA,** Permian Basin Regional Meeting, Lincoln Hotel, Odessa, Texas.
22–24	**ISA, AIEE, ARS, IAS, IRE,** National Telemetering Conference, Chicago.
June	
5– 8	**ISA,** Summer Instrument-Automation Conference & Exhibit, Royal York Hotel, Queen Elizabeth Hall, Toronto, Ont.
13–16	**ISA,** Gas Chromatography Symposium, Kellogg Center, Michigan State University, East Lansing, Mich.

For more data on advertised products, use Readers' Service Cards, last page.

In the design of these MEA Absorbers and Strippers

INTALOX SADDLES

- **Saved 20% in height**
- **40% in gas pumping costs**

GEECO

The Gas Equipment Engineering Corporation of Mount Vernon, N. Y. designed and erected a 30 ton-per-day CO_2 generating plant. Two six foot diameter columns were used for absorbing carbon dioxide gas using MEA as the solvent. By using INTALOX Saddles for the tower packing, it was possible to reduce the tower height 20% below what would have been required with Raschig Rings.

Not only was the capital cost greatly reduced but the columns performed even better than design requirements. Operating costs were also less because the appreciably lower pressure drop led to a 40% reduction in gas pumping expense. In addition, the greater-than-design scrubbing efficiency led to increased CO_2 recovery.

In mass transfer operations involving packed towers the use of Intalox Saddles almost invariably means increased capacities, lower pressure drops, and. of course, lower initial and operating costs.

U. S. STONEWARE

AKRON 9, OHIO

OUR 101st YEAR

NEW YORK • CHICAGO • HOUSTON • LOS ANGELES

Would you like to know more about INTALOX SADDLES? Write for Bulletin S-29R

388-F

Don't tube up your heat exchangers without calling Chase®

Chase Heat Exchanger Tube Clinic

Provides Complete 8-Point Service

It's just plain common sense to talk to Chase first—before you order tube for original equipment or for retubing. Here's why: The Chase Tube Clinic has a special 8-point program that's ready to serve you in all these ways:

1. **WATER ANALYSIS** – either original or recheck, to help eliminate failure.
2. **TUBE FAILURE ANALYSIS**—by examination of sections of defective tube, determine why the failure and how to avoid repetition.
3. **CORROSION SERVICE**—predicts where to look for trouble based on the collected experience with water samples and service conditions from hundreds of areas all across the country.
4. **PRODUCT QUALITY CONTROL**—Chase tube meets rigid ASTM specs, and is given special Chase-developed electronic tests as well.
5. **WIDE ALLOY CHOICE**—Chase has the alloy available (brass, copper, aluminum, stainless or bimetal) to meet any combination of service conditions.
6. **STRATEGICALLY-LOCATED STOCKS** and mills can meet normal or emergency delivery schedules.
7. **APPLICATION ADVICE**—Chase tube engineering staff can help with design of tube sheets; welding or rolling-in installations; advice on use of inserts; selection of dual-gauge or thickened end tube, etc.
8. **PACKAGING TO SPECIFICATION**—When you order tube from Chase, it comes fully protected against damage, and in job-designed packaging to meet your exact specifications and installation needs.

Get in touch with the exclusive Chase Tube Clinic today—by calling your nearest Chase Representative, or by checking and mailing the coupon below.

Chase

BRASS & COPPER CO. WATERBURY 20, CONN.
Subsidiary of ***Kennecott Copper Corporation***

CHASE BRASS & COPPER CO.
DEPT. PR-11, WATERBURY 20, CONN.

Please send me the following literature:

☐ Condenser Tube ☐ Information on welding installations
☐ U. Bends ☐ Full details on how to take advantage of Chase Tube Clinic Service

NAME_____ TITLE_____

COMPANY NAME_____

STREET ADDRESS_____

CITY_____ ZONE____ STATE_____

For more data on advertised products, use Readers' Service Cards, last page.

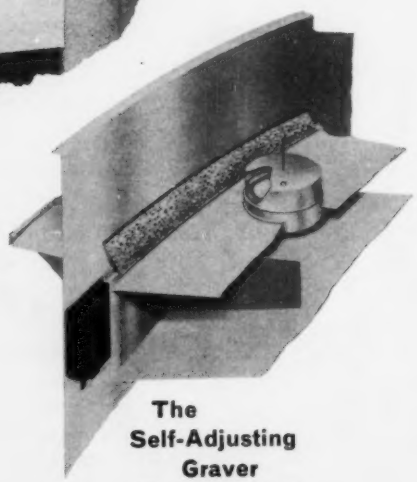
An ounce of pressure is worth being sure...

Just one ounce of pressure is needed to keep the Graver Pressure Seal at work preventing vapor loss in floating roof tanks.

The Pressure Seal, inflated with air, expands to fill the varying gap between the roof and the shell of the tank, thus assuring sustained contact against the shell better than any solid or liquid pressure-type seal.

In addition to preventing loss of vapor, the Graver Pressure Seal minimizes corrosion . . . adds to the fire-resistant characteristics of floating roof tanks.

Write us today for information on how Graver floating roof tanks with the Pressure Seal can help you with your tankage problems.



The Self-Adjusting Graver Pressure Seal

Graver

ONE OF THE UNION TANK CAR COMPANIES

Graver Tank & Mfg. Co.

EAST CHICAGO, INDIANA

PLANTS AND OFFICES ACROSS AMERICA

Changing Times (Continued)

API awards $5,000 to Dr. John S. Rinehart for research. Rinehart is director of the Colorado School of Mines' mining engineering research laboratories.

Three subsidiaries of Godfrey L. Cabot, Inc., merged to form Cabot Corp. Godfrey L. Cabot, Inc., Cabot Carbon Co., Cabot Shops, Inc., and Cabot Gasoline Corp. form the Delaware corporation.

Allied Chemical Co. combines polyethylene manufacturing and marketing with other plastics to form Plastics Division. The realignment is an effort to strengthen efficiency in competitive plastics areas.

Coal is gradually becoming a top competitor with oil in Great Britain, according to Alfred Robens, chairman-designate of Britain's National Coal Board.

ISA awards Dr. Allen V. Astin, director of National Bureau of Standards, lifetime honorary membership. He is the eighth man to be so honored by the society since it was founded in 1946.

Houdry Process Corp., Philadelphia, and Chemische Werke Huels, Marl, West Germany, form company to develop, manufacture and sell catalysts. The new firm, Katalysatorenwerke Houdry-Huels G.m.b.H., will be located in Marl, where catalysts will be produced and sold to the Western European market.

Stockholders, Standard Oil Co. (Indiana), give landslide approval to proposed corporate reorganization at special meeting. More than 88 percent of the firm's approximately 35,100,000 outstanding shares were voted for the reorganization, with less than one-third of 1 percent against it.

Grant totaling $40,000 made to Ohio Foundation of Independent Colleges by The Standard Oil Co. (Ohio). The money will be used partly to continue Sohio scholarship plan.

Plans to merge four subsidiaries from Rocky Mountains eastward into single corporation by Standard Oil Co. of California complete. The new firm is California Oil Co. Companies merged are: Standard Oil Co. of Texas, California Oil Co., Salt Lake Refining Co., and The California Co.

Quest for national fuels policy by the coal industry has been criticized by J. L. Lenker, Gulf Oil Co. vice president, as being a short-sighted solution to coal marketing problems.

Investments in petroleum in foreign countries by United States companies in 1959 amounted to $10.4 billion, compared to $9.8 billion in 1958, according to a report by the U. S. Department of Commerce.

How to detect moisture down to one part per million

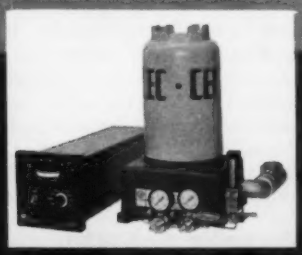
CEC makes it easy, with the most complete line of moisture monitoring equipment on the market.

If you are faced with problems in product or system contamination by water, look into the capabilities of these rugged, reliable instruments:

26-301 and 26-302 Portable Moisture Monitors **– For lab and field use, the 26-301 measures water content of gas from 1-1000 ppm; the 26-302 measures from 1-20,000 ppm. Both units operate on 110V line power or accessory battery pack.** ***Bulletin CEC 1834-X9.***

26-350 High-Pressure Moisture Monitor **– Designed initially for missile checkout, this instrument also tests water concentrations in high-pressure gas for many commercial applications. Maximum operating pressure is 6000 psig.** ***Bulletin CEC 1855-X10.***

26-310 Process Moisture Monitor **for plant monitoring of gaseous process streams. The explosion-proof analyzer mounts directly on-stream. Remote control and continuous readout are provided in the control room.** ***Bulletin CEC 1845-X32.***



CEC's 26-312 Liquid Process Moisture Monitor — The only instrument in existence for continuous and accurate measurement of water content in liquid-process streams. Bulletin CEC 26312-X3.

Analytical & Control Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

A SUBSIDIARY OF Bell & Howell · *FINER PRODUCTS THROUGH IMAGINATION*

Men In Industry...

Eugene Holman, former president and board chairman of Standard Oil Co. (New Jersey), has been named the 1960 recipient of American Petroleum Institute's "Gold Medal for Distinguished Achievement." Holman spent about 40 years in the oil industry before retiring from Jersey Standard May 1 of this year. He became a director of the company in 1940. Two years later he was elected a vice president and then a member of the executive committee. He became president in June 1944 and chairman of the executive committee in January 1946. He became chairman of the board of directors Jan. 1, 1954. He is the twelfth recipient of API's Gold Medal, which was last awarded in 1958 to **W. S. Rodgers,** former president and board chairman of The Texas Co.

Holman

E. D. Brockett has been elected president of Gulf Oil Corp. He was formerly an executive vice president of the company. From 1955 until 1957, he was vice president in charge of the company's Houston Production Division. Second to **W. L. Mellon,** one of the firm founders who became president at the age of 41, Brockett is the youngest man to be president of Gulf Oil. He is 47. Brockett replaces **W. K. Whiteford,** who was company president since 1953.

Monroe E. Spaght has been elected president, Shell Oil Co. Spaght was hired 27 years ago by Shell as a research chemist. He has been executive vice president since 1953, and before that headed Shell Development Co., a research affiliate. He succeeds **H. M. S. Burns,** who will retire December 31.

Dudley Tower has been elected president, Union Oil Co. of California. Tower had been executive vice president since last April. He replaces **Reese H. Taylor,** who will continue as chairman and chief executive officer of the company. Tower joined Union Oil in 1935 in Long Beach, Calif. He later became district engineer for the firm's operations in Houston, and in 1946 was named manager of operations for the Gulf Division. He became a vice president in 1953.

P. L. Smith, manager of Mobil Oil Co.'s Beaumont, Texas refinery, will retire January 1 after 37 years' service. He will be succeeded by **L. E. Cranston,** manager of Mobil's Paulsboro, N.J., refinery. Four other changes in refinery personnel will also take place. **R. C. Hartman,** operating superintendent at Paulsboro, will replace **W. W. Reed** at East Chicago, Ind. **W. B. Kleihege,** assistant manager at East Chicago, will succeed **E. T. Pummill** at the Casper, Wyo., refinery. The new manager at Paulsboro will be **S. W. Thomson,** now assistant manager there. **B. L. Rodzianko,** now in charge of the East Providence, R.I., plant, will become assistant manager at Paulsboro, and will be succeeded by **A. H. Fuller,** now engineering and maintenance superintendent at East Providence. **R. E. Maescher,** operating superintendent at Torrance, Calif., will replace Hartman as operating superintendent at Paulsboro.

Thomas G. Reynolds has become project manager of the engineering staff, SunOlin Chemical Co. at its headquarters in Philadelphia. **H. Harold Bulkowski** and **Manlio M. Mattia,** both process engineers, and **Samuel L. Palese,** a civil engineer, have also joined the engineering staff. Reynolds is in charge of all auxiliary plants connected with SunOlin's ethylene and ethylene oxide production. The other men are engaged in engineering plans for expansion.

Dan B. McVickar and Dr. Bernard L. Meyers have joined the Whiting Research Laboratories, Standard Oil Co. (Indiana). McVickar will carry out studies to improve the antiknock quality of gasoline. Dr. Meyers will study new ways of applying X-ray analysis to the evaluation of petroleum products.

Alexander B. Clarke, manager of The Standard Oil Co. of Ohio, Manufacturing Department, has been named vice president for manufacturing.

Edward W. Midlam, staff executive, Manufacturing Department, Cities Service Petroleum, Inc., has been elected vice president and general manager, and a director of Cit-Con Oil Corp. Cit-Con, which produces a wide variety of lubricating oils and petroleum waxes at its Lake Charles, La., plant, is owned by Cities Service Co. and Continental Oil Co. Midlam began his petroleum career as a research engineer for Socony-Vacuum Oil Co. in 1931 and afterward was employed by Max B. Miller & Co., Inc. In 1950 he joined the Cit-Con organization as a process engineer, and a year later became manager of technical services. He held that position until 1957 when he was appointed staff executive for Cities Service Petroleum, Inc.

Dr. Raymond Wynkoop has been appointed director, Commercial Development Division, Sun Oil Co.'s Research and Engineering Department. **Dr. Egbert M. Kipp** has been named to succeed Dr. Wynkoop as manager of Sun's basic research. Dr. Wynkoop graduated from Worcester (Mass.) Polytechnic Institute with a B. S. degree in chemical engineering in 1942, and received his doctorate in chemistry and chemical engineering from Princeton University in 1948. He joined Sun Oil as assistant director, petrochemicals, Research and Development Division in 1958. He was named manager of basic research a year later.

James E. Kehoe, Jr., has been awarded $5,000 by Esso Standard Division, Humble Oil & Refining Co. The payment was for an employe suggestion Kehoe submitted in 1959. His award was the largest ever received by a New York headquarters employe of any affiliate of Standard Oil Co. (New Jersey), a parent company of Humble and Esso. Kehoe's $5,000 suggestion involved the production of an important raw material for lubricating-oil additives. Esso had been purchasing it from outside suppliers. As a result of the suggestion, Esso found it could adapt one of its refinery processes and manufacture the raw material itself. The suggestion not only meant a substantial monetary saving, but it facilitated lubricating-oil production and helped insure that supply would meet demand.

Kehoe

Louis N. Carmouche has been appointed general manager, Saginaw Bay Division, The Dow Chemical Co., Bay

Bristol Dynamaster* Electronic Instruments have proved themselves in thousands of installations. They fully meet today's most exacting standards of accuracy and dependability. They measure almost any variable that can be translated into an electrical quantity (d-c current, d-c voltage, resistance or capacitance). Just a few are: temperature, pH, speed, voltage, smoke density and strain.

Here are some outstanding features that make them ideal for industrial plants, pilot plants, and for research, test, and laboratory use:

1. Continuous standardization—eliminates standardizing mechanism and dry cell—no interruption to control. **But retains precision standard cell for highest accuracy and stability.**

2. Simple design—few moving parts.

3. Easy to use and service—little or no maintenance required.

4. Rugged construction—unaffected by vibration.

look to Bristol for the complete line of

ELECTRONIC POTENTIOMETER and BRIDGE INSTRUMENTS

MODELS FOR EVERY PURPOSE. Dynamaster Instruments are now available as:

A. Single-pen, two-pen, and multiple-record (up to 24 points) strip-chart instruments.

B. One- and two-pen round-chart recorders.

C. High-speed recorders (0.4 second).

D. X-Y recorders.

E. Extended range recorders.

F. Adjustable span and zero recorders.

G. Miniature 3-inch strip-chart recorders.

H. Electric controllers in both strip- and round-chart models—all types of control action and as time-program control.

I. Pneumatic controllers in both strip- and round-chart models—all types of control action and time-program control.

J. Instruments for electronic measurement—pneumatic transmission of reading by 3-15 psi signal.

K. Round chart program controllers.

L. Telemetering transmitters.

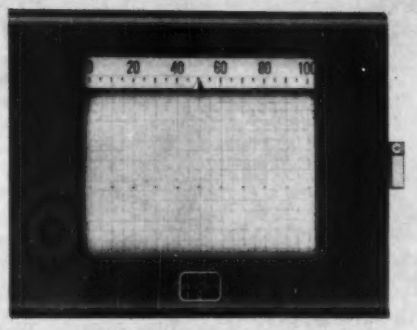
M. Drum-type precision indicators.

N. Multi-bank recorder—will accept up to 200 separate inputs and record them on 12-inch wide strip chart.

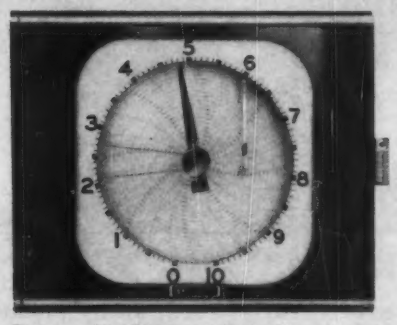
O. Relay-rack mounting models—most models available in case that fits standard 19" relay-rack without modification to instrument or rack, without panel-cutting or masking.

Bristol Dynamaster Potentiometer and Bridge Instruments can be equipped with analog-to-digital encoders of various types for digital readout and computer use. For complete details, write for Bulletins P1245A, P1270, P1271, P1242, and P1282. The Bristol Company, 111 Bristol Road, Waterbury 20, Conn.

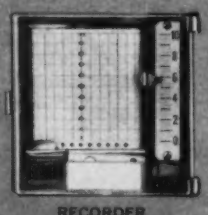
*T. M. Reg. U. S. Pat. Off.



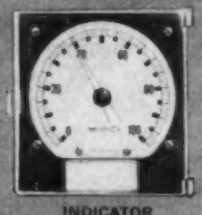
Dynamaster* Electronic Potentiometer or Bridge—records on 11-inch, 120-foot-long strip chart.



Dynamaster* Electronic Potentiometer or Bridge—records on 12-inch round chart, indicates on extra-large scale.



RECORDER



INDICATOR

Plug-in Miniature Electronic Dynamaster Potentiometer and Bridge Instruments—Only 5" x 5⅛" panel dimensions; ideal for graphic panel instrumentation.

BRISTOL

TRAIL-BLAZERS IN PROCESS AUTOMATION

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Men . . .

City, Mich. Carmouche, who was manager of the Ludington Division since 1946, will be succeeded by **John W. Corey.** Corey has been director of the research and development laboratory at Ludington and in charge of type B catalyst production there since 1958.

Vincent R. D'Alessandro has been appointed director of industrial relations for Sinclair Oil Corp. and its subsidiaries. He joined the Industrial Relations Department of Sinclair 15 years ago. In his new position, he will be responsible for all functions relating to the handling of union relations of Sinclair.

R. W. Hall, formerly manager, Technical Services Division of Texaco, Inc., Beacon, N.Y., has been transferred to Houston as manager of a newly established Research and Technical Department managerial office. Hall will be in charge of liaison between the Research and Technical Department and Texaco's refining and engineering managerial groups as well as other departments and subsidiaries of the company headquartered in Houston. **R. F. Nelson,** formerly director of Texaco's technical services group at Port Arthur, and **C. L. Crawley,** research associate at Port Arthur, have been assigned to the Research and Technical Department's managerial office as assistants to the manager.

Rexford S. Blazer, Ashland Oil & Refining Co., has been reelected to a second term as president, National Petroleum Association. The election took place at the 58th annual meeting of the NPA in Atlantic City, N. J. Also reelected were: **John E. Selden,** South Penn Oil Co., first vice president; **L. E. Kincannon,** Rock Island Refining Corp., second vice president; **Guy B. Hunter,** Quaker State Oil Refining Corp., treasurer, and **O. P. Keeney,** Oil City, Pa., recording secretary.

D. R. Moore has been promoted to supervising engineer and **R. J. Davis** and **R. C. Wahrmund** to staff engineers,

Davis

Wahrmund

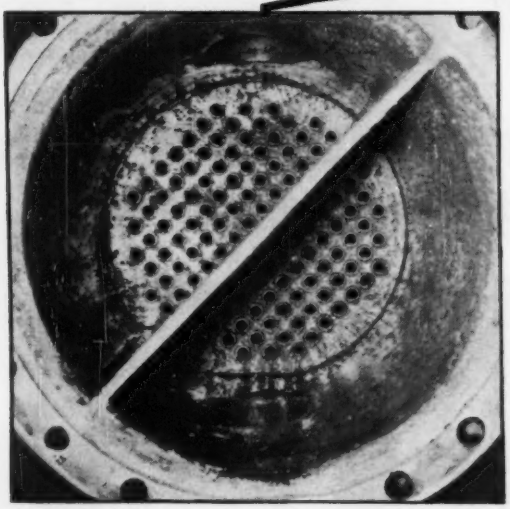
Technical Division, Baytown, Texas, Refinery, Humble Oil & Refining Co.'s Humble Division. Moore heads the section that is responsible for long-range planning, and developing major projects in all phases of fuel and specialties operations. In the operations services section, Davis handles controls and systems engineering and serves as a consultant to other divisions. Wahrmund is in the process engineering section and handles process design of major refining and chemical units. Moore holds a B.S. degree in chemical engineering from the University of Taxas, Davis a B. S. degree in electrical engineering from Texas Technological College, and Wahrmund a B. S. degree in mechanical engineering from the University of Texas.

Moore

Dr. L. H. Berryman has been appointed senior research physicist, geophysics development section, La Habra Laboratory, California Research Corp. Berryman received a Ph.D. degree in physics from the University of Oklahoma in 1950. He taught physics and conducted research at the University of

Positive Control for Slime and Algae!

WRIGHT'S *New* TQC*



BEFORE the application of Wrico TQC, the tubes, shown above, were nearly closed with slime. Tuberculation of the water box occurred because a slime coating prevented the corrosion inhibitor from effectively contacting the metal. Three treatments with Wrico TQC killed the slime, allowing the corrosion inhibitor to be fully effective.

Where algae is concerned, a Texas refiner said, "Our towers have always had very bad algae problems although we've tried many products. We now apply Wrico TQC weekly and have no sign of algae."

Another use for Wrico TQC is in spray programs for preserving tower wood, as it is exceptionally effective against fungal growths.

Try New Wrico TQC where you have slime, algae or fungal problems—it's positive, easily used and reasonable in cost. Write for details.

** A new development of Wright Chemical Laboratories . . . patent applied for.*

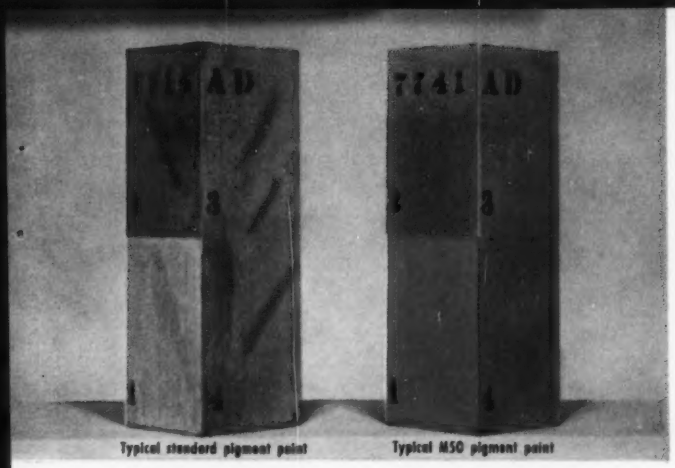
Wright CHEMICALS

WRIGHT CHEMICAL CORPORATION

GENERAL OFFICES AND LABORATORY: 615 W. LAKE ST., CHICAGO 6, ILL.

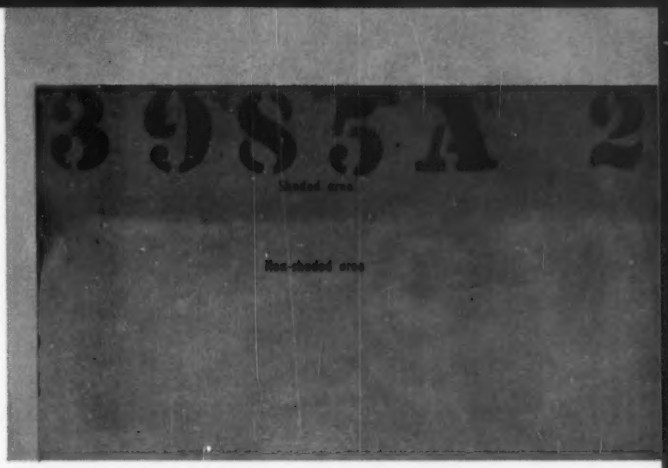
Offices in Principal Cities

For more data on advertised products, use Readers' Service Cards, last page.



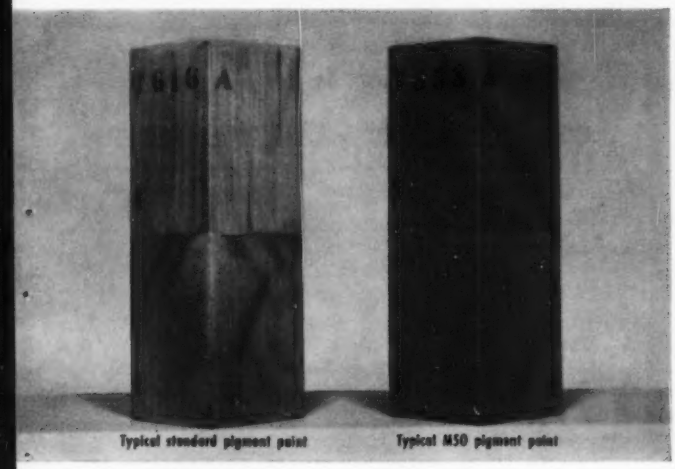
No objectionable whitening from chalking

Contrast these two exposure test panels . . . both show comparable metal finish paints. Same original colors. Same exposure (45° South, 2 yrs., 3 mos.). Notice bright color of *M50* paint, freedom from chalk.



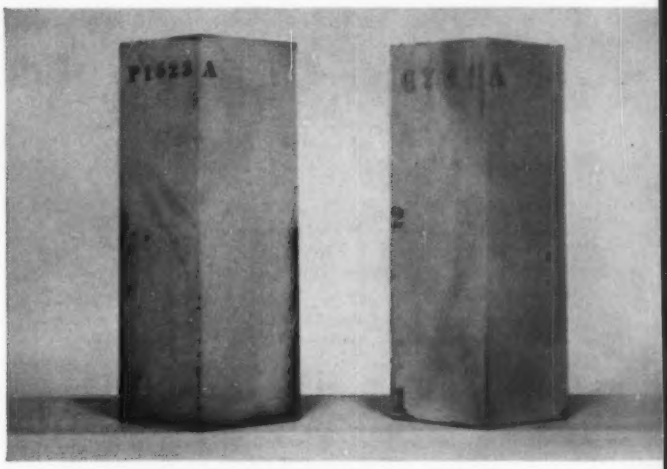
No appreciable fading from light action

Now look at this 9-year exposure test panel of an *M50* paint. Contrast area shaded by wooden panel holder with non-shaded area. Clearly, there has been practically no fading in this 9-year period.



No leaching from water action

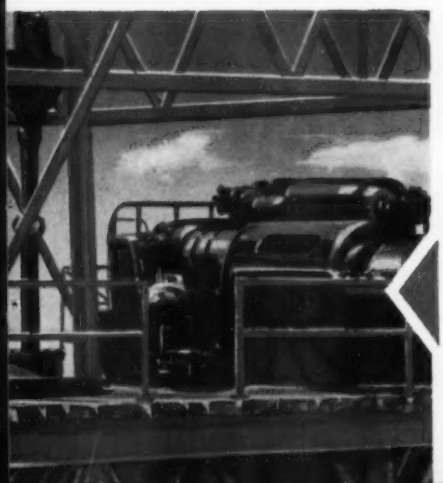
Examine the exposure panel at left. Notice the vertical brushmarks? Rain water leaching of the top coat permits brushmarks in undercoat to show through. In the panel at right, insoluble *M50* pigment prevents this film failure. Exposure 45° South, 2 yrs., 7 mos.



No discoloration in industrial atmosphere

Here are two exposure panels painted from the same can of *M50* paint. Both have been exposed 4 years, 45° South. The right one in normal atmosphere, the other in sulfur-laden industrial atmosphere. Notice no color difference has developed. No bilging.

Proof you get unique color stability in metal protective paints made with M50® pigment



Drilling equipment looks better, needs less maintenance painting when painted with colorful *M50* anti-corrosion paints.

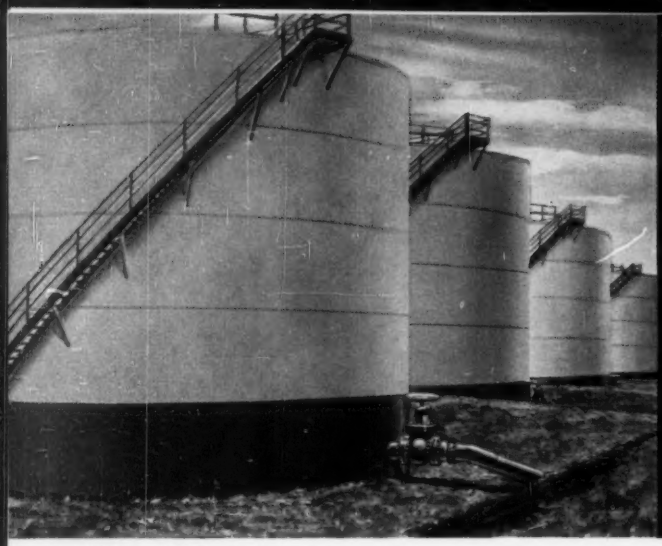
No need to amplify what the four illustrations above show. Plainly, *M50* basic lead silico chromate pigment permits your paint supplier to make paints with more color stability than ever before available in anti-corrosion paints . . . primers as well as finishes.

National Lead exposure tests demonstrate that these paints . . . both standard and deep-coat . . . also provide better and longer lasting anti-corrosion action, and never-before weather resistance. Some of the opportunities these new *M50* paints present are suggested on the following page. You'll think of others.

M50 *an* **oncor** ® *pigment development of*

National Lead Company

111 Broadway, New York 6, N. Y.



Public relations.
Attractive tank farms that *stay* attractive longer.

Product identification.
Color-coded drums that *stay* colorful longer.

Two ways to make good use of the superior color stability of M50 pigment anti-corrosion paints

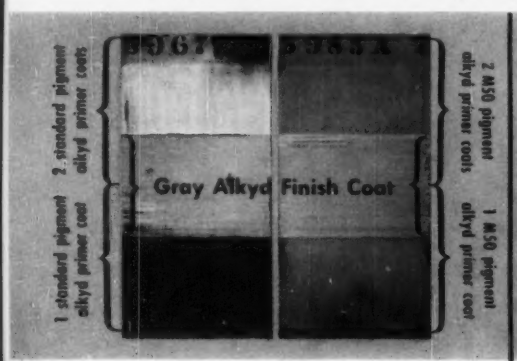
Before the advent of *M50* pigment, those responsible for maintenance painting had to make a choice between colorful appearance and long-lasting corrosion protection.

With *M50* pigment paints, exposure experience proves, this compromise is no longer necessary. *M50* paints have weather resistance . . . stay bright and colorful . . . and *at the same time* provide superior corrosion protection. With these unusual paints, color stability problems . . . leaching, fading, whitening, darkening from bilging . . . are eliminated. Now, with *M50* paints, you can have maximum anti-corrosion, maximum durability and, at the same time, long-lasting good appearance.

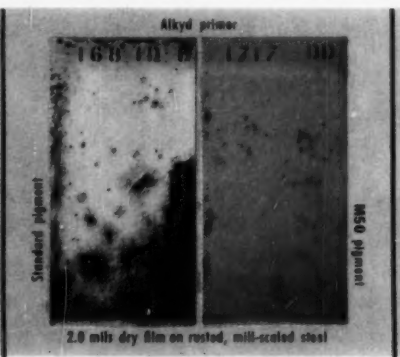
The illustrations above suggest two areas in which the combination of superior anti-corrosion action and superior color stability found in *M50* pigment paints can pay off handsomely. Note that in both, service is severe and colorful colors are needed. With *M50* paints, you repaint less often.

In your own operations there are bound to be many similar applications where specification of *M50* paints can lower your maintenance painting costs. Ask your regular paint supplier to make up suitable *M50* paints for your requirements.

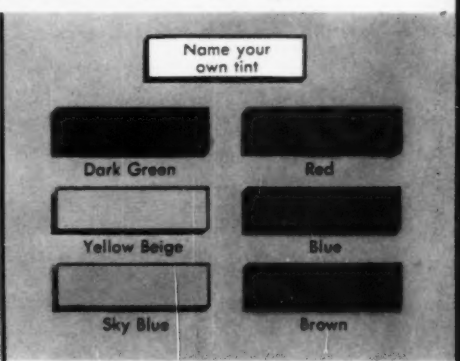
Why M50 Defense in Depth paints give anti-corrosion beyond all former concepts


2 standard pigment alkyd primer coats
1 standard pigment alkyd primer coat
Gray Alkyd Finish Coat
2 M50 pigment alkyd primer coats
1 M50 pigment alkyd primer coat

Exposed 9 years, 45°S. Each coat 1.5 mils
Proved corrosion and weather resistance



Exposed 45°S, 1 yr ind. atmos., 1 yr normal atmos.
Proved outstanding for film strength, durability



Colors above available in conventional and heavy-coat paints
A wide range of stable colors can be produced

Are you concerned with tank or structure maintenance painting in your firm? If so, you are invited: (1) to visit National Lead's Sayville, L.I. test station, where you will see the results of the 20 years research that lies behind the *M50* pigment particle and the more than 10 years of exposure testing that lies behind *M50* pigment Defense in Depth paints; (2) to send coupon below for National Lead booklet, "Defense in Depth" and typical *M50* tank paint specifications.

Next time you purchase, specify *M50* pigment paints. Any paint manufacturer can supply you.

M50 Defense in Depth

National Lead Company,
111 Broadway, New York 6, N. Y.

Gentlemen: Please send me the "Defense in Depth" booklet together with typical tank paint formulas and color chips that I can use in specifying M50-type tank paints.

Name_____ Title_____

Firm or Dept._____

Address_____

City_____ State_____

Men . . .

North Carolina until 1954, when he joined Continental Oil Co. to do geophysical research and development.

R. B. Thompson has been named manager, Technical Department, Mobil

Turkleson

McKellar

Chemical Co., Beaumont, Texas, plant. **R. E. Turkleson** has been appointed manager, Production Department, and **W. E. McKellar, Jr.,** has been promoted to manager, Employe Relations Department. Thompson will be responsible for process engineering, design engineering, economics, control laboratory, plant maintenance and planning. Turkleson will handle production and distribution in the Beaumont area. McKellar's duties will include policy administration, safety, plant security, and training.

Thompson

John H. Strange has been named administrative assistant to the general manager of research and development, Standard Oil Co. (Indiana) Chicago office. At the company's Whiting, Ind., laboratories, **Morris T. Carpenter** and **Thomas G. Stack** have been appointed assistant directors of administration. **Donald G. Schroeter** replaces Stack as superintendent of employe relations.

Hugh H. Millar, W. Turner Clack, John L. Kalb and **H. R. Milner,** all Directors of Husky Oil Co., have been elected to the board of directors, Canadian Husky Oil Co. This mass election makes the membership of both boards identical.

Karl A. Muller, chemical engineer, has been promoted to senior chemical engineer, American Oil Co.'s Texas City, refinery. **Clifton N. Sechrist** and **Manford R. Haxton** have been advanced to group leaders in chemical research. **P. J. Naquin,** assistant chemical engineer, has

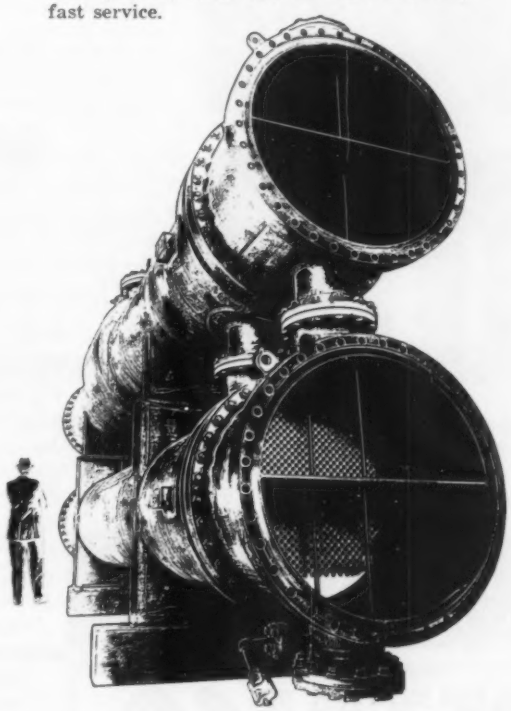
SWECO'S ONE MAN PLAN

Process equipment purchasing is an intricate undertaking . . . that's why SWECO assigns *ONE MAN* as sales engineer to coordinate and expedite your project.

He communicates your equipment rating and performance data to SWECO's staff of engineering specialists. Experts in meeting the challenges of new extremes in temperature and pressure, they develop improved designs and methods for most efficient and economical operation of process equipment.

He draws upon SWECO's 40 years experience in fabricating heat exchangers, pressure vessels and steam jet ejectors, from a wide range of metals and alloys. SWECO's know-how pays off for you in high-quality standards and reasonable production costs.

Your equipment is the responsibility of your SWECO project coordinator from design and production, until units are installed and operating to your satisfaction. He *knows* your project, gives you straight answers, fast service.



For details on SWECO heat exchangers, pressure vessels, steam jet ejectors and other equipment, write for Bulletin 16-333.

SWECO

Southwestern Engineering Company

4800 Santa Fe Avenue, Los Angeles 58, California

ENGINEERS — CONSTRUCTORS — MANUFACTURERS

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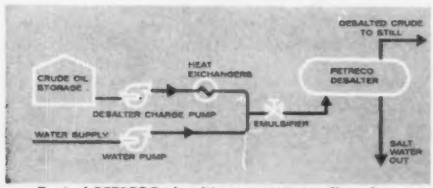
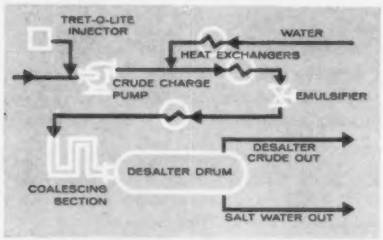
How PETRECO Processes Work...

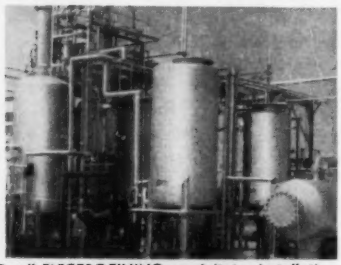
TO IMPROVE PRODUCTS...CUT TREATING COSTS



Typical PETRECO desalting precipitator flow diagram.



TRET-O-LITE desalting flow diagram.



Small ELECTROFINING precipitator installation.

BENDER sweetening installation.

** Trademarks, Petrolite Corporation*

PETRECO *Electric Desalting*

The crude charge is pumped through a heat source with temperatures in the 225-275°F. range, then mixed with a small quantity of water and emulsified. Resulting water-in-oil emulsion is then dispersed into high-potential electrostatic field. Powerful coalescing action forces intimate association of impurities (salts and other solids) with water. Water is then quickly and automatically separated and withdrawn. Purified crude continues into refinery flow.

Tret-O-LitE *Chemical Desalting

Chemical is injected into suction side of charge pump to assure dispersion. Wash water (about 5% of oil volume) is added to oil-chemical mixture following the charge pump. This oil-chemical-water mix is raised to operating temperature and water-to-oil contact attained by passing through emulsifying valve following heat exchangers. Resulting emulsion then goes through coalescing section where water droplets grow to size that permits separation. Mixture then enters desalting vessel, salt-in-water separates from hydrocarbon phase. Purified crude proceeds to usual distillation equipment.

ELECTROFINING *Precipitators

In this treatment, the distillate is intimately and intensively contacted with a predetermined amount of treating chemical. Controlled intimacy of contact minimizes treating time. The hydrocarbon and treating chemical phases then are rapidly separated by the precipitating action of the strong electrostatic field. With ELECTROFINING* Precipitators, distillate stocks can be treated with caustic to remove acids, hydrogen sulfide, lighter mercaptans, gum-forming components. Cracked stocks can be treated to remove cresols and thiocresols. Sulfuric acid treatment removes sulfur compounds, gum and sediment forming materials, nitrogen bases, arsenic, lead, etc.

BENDER Catalytic Sweetening

Controlled quantities of sulfur, alkali and air are added to the charge stream, then passed through a PETRECO* catalyst bed. The mercaptans are converted to disulfides by oxidation. The resulting product is sweet and non-corrosive. The BENDER process is simple, continuous and automatic.

OTHER PETRECO PROCESSES INCLUDE:

PETRECO *Dehydration
PETRECO *Desaponification
PETRECO *Sediment Separation

FOR MORE INFORMATION on any of these treating processes, contact your local Petreco service engineer, or write...

AR-60-2

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GERMANY: Petrolite Anlagenbau und Vertriebsgesellschaft m.b.H., Frankfurt a. M.
VENEZUELA: South American Petrolite Corporation, Hotel Avila, Caracas

PETRECO DIVISION
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MEXICO: R. E. Power, Sierra de Mijes No. 125, Mexico, D. F.
NETHERLANDS: F. E. C. Jenkins, Hoefbladlaan 134, The Hague
TRINIDAD: Neal and Massy, Ltd., P. O. Box 544, Port of Spain

For more data on advertised products, use Readers' Service Cards, last page.

Men . . .

been named associate chemical engineer at the refinery. Marion B. Sterling, assistant construction and maintenance engineer, has been advanced to associate construction and maintenance engineer.

Robert L. Brown has been appointed manager, Systems and Procedures Department, Sinclair Oil & Gas Co. **George V. B. Pearson,** who joined Sinclair in

Brown

Pearson

1917, in Tulsa, has retired. Pearson was in charge of systems and procedures. Brown joined the company in 1936 as a roustabout.

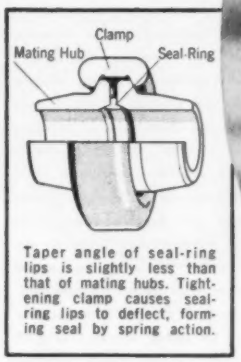
R. J. Metcalf, formerly manager, operations, Gulf Oil Corp.'s Philadelphia refinery, has been promoted to general manager of the company's Cincinnati refinery. **W. S. Bonnell** has been appointed manager, operations, at the Philadelphia refinery. Bonnell was previously director, chemical Processing Division, Port Arthur, Texas.

F. Leonard Bryant, a vice president of Hooker Chemical Corp. since 1957, has been elected executive vice president and a director of the corporation. Bryant, a native of Weymouth, Mass., has been with Hooker since 1935 when he graduated from Dartmouth University with a B.A. degree in chemistry.

Roy J. Diwoky, president of Commonwealth Oil Refining Co., has been named chairman of the board. **Sam H. Casey,** executive vice president, has succeeded Diwoky as president and chief executive officer.

J. Byron Eckert, regional executive for the Middle East for Mobil International Oil Co., has been appointed regional executive for North Africa, France and Spain. He is replacing **Arthur G. Reed,** who is retiring December 1.

Lindsay I. Griffin has joined Esso Research and Engineering Co. on a rotational assignment from the affiliated Esso Research Laboratories, Baton Rouge, La. He will be concerned with



Taper angle of seal-ring lips is slightly less than that of mating hubs. Tightening clamp causes sealing lips to deflect, forming seal by spring action.

GRAYLOC PIPE CONNECTIONS HOLD PRESSURE WITHOUT LEAKING

From a full vacuum to extreme internal pressure, GRAYLOC pipe connections will not leak—will not blow out.

It's an all steel assembly with a pressure aided seal that can be quickly and easily disconnected. The seal ring is even re-usable! Yet, for all its sealing power, it's lightweight and small in size.

GRAYLOC pipe connections are manufactured in standard stock sizes from 1″ to 30″, but special sizes can be manufactured on request. They are also available made of corrosion resistant metals.

Learn how GRAYLOC pipe connections can save you time, space and money. Write for the all new GRAYLOC catalog.

GRAYLOC SALES DIVISION

GRAY Tool Company

6006 P. O. BOX 2291 HOUSTON 1, TEXAS Riverside 7-1240

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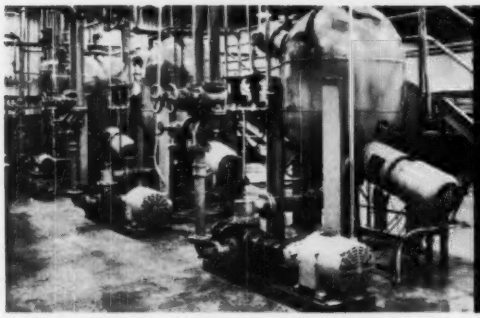
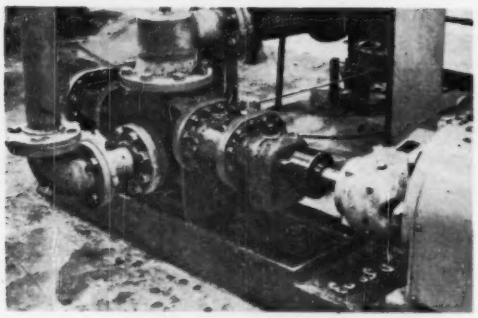
For High-Viscosity Pumping--



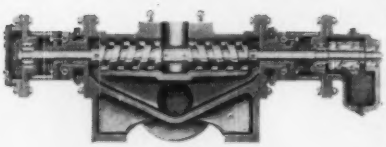
specify *Sier-Bath* SCREW PUMPS

SHUFORD MILLS pumps rubber-resin adhesives of 700,000 SSU at 140°F.

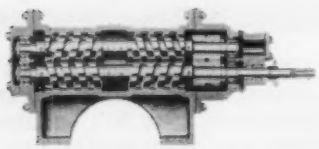


• At Shuford Mills, manufacturers of pressure sensitive tapes, 5 Sier-Bath Pumps transfer heavy liquid adhesive from mixing tanks to storage tanks. These mixtures, consisting of toluene, MEK, natural rubber, synthetic rubber, resin and additives, have been pumped by Sier-Bath Screw Pumps with good success since 1955. All gears and bearings are externally mounted to avoid contact with materials pumped. A Sier-Bath Hydrex Pump is also used to pump varnish and a Sier-Bath Gearex Pump handles toluene and MEK solvents.

Sier-Bath **SCREW PUMPS**



External Gear and Bearing Bracket Type for non-lubricating liquids and semi-liquids



Internal Gear and Bearing Type for lubricating liquids and semi-liquids

Sier-Bath Screw Pumps maintain high volumetric efficiency because "Dual-Controlled" precision rotor design prevents rotor-to-rotor or rotor-to-casing contact—provides a continuous flow without pulsation, hammering or vibration . . . without strains, misalignment and wear on rotors, shafts, bearings and gears.

Result: Dependable, uninterrupted pumping service—less maintenance—easier servicing—longer pump life—lower overall pumping costs.

Capacities from 1 to 2,000 gpm.; viscosities from 32 SSU to 1,000,000 SSU.; discharge to 1,000 psi. for viscous liquids, 200 psi. for water and light oils. Horizontal or vertical construction. Corrosion resistant alloys, special bodies, stuffing boxes and bearings for special needs. See "Yellow Pages" for your Sier-Bath representative or write Sier-Bath Gear & Pump Co., Inc., 9261 Hudson Blvd., North Bergen, N. J.

Sier-Bath ROTARY PUMPS

Screw Pumps Gearex® Pumps Hydrex® Pumps

Founded 1905 Mfrs. of Precision Gears, Rotary Pumps, Flexible Gear Couplings Member A.G.M.A.

Men . . .

conducting special studies in the firm's Products Research Division. Dr. Griffin, a graduate of The University of Texas with a doctorate in chemical engineering, has been with Esso for 21 years. He has worked principally on the development of fuels processes including catalytic cracking, hydrocarbon synthesis, isomerization and fluid coking.

Jason Cooper, Jr., has been named employe relations manager, Esso Standard Division, Humble Oil & Refining Co. **J. Edwin Hughey** acting employe relations manager, becomes administrative assistant to Esso president, **William W. Bryan.** Cooper has been coordinator of

Cooper

Hughey

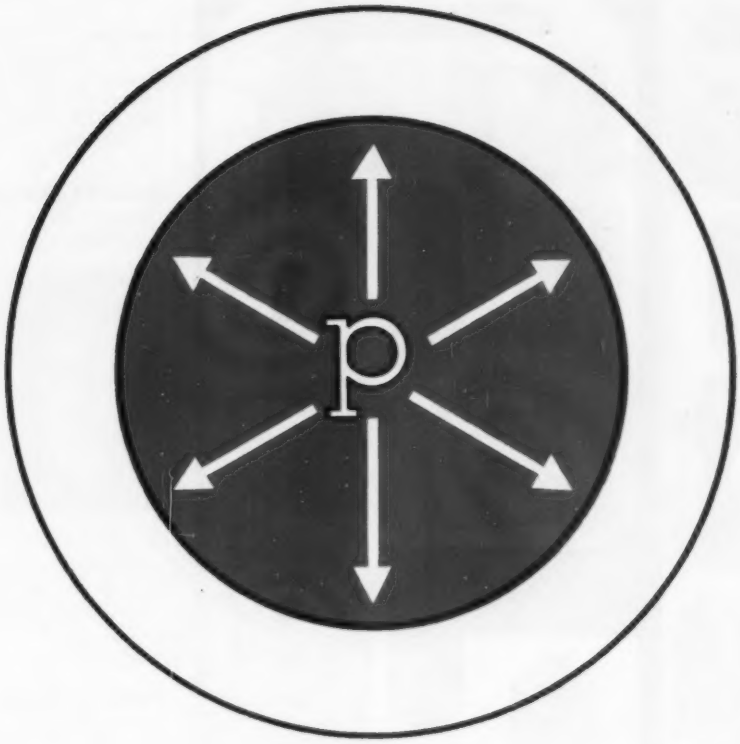
management development and retains responsibility for Esso's management development program, in addition to his new duties. Hughey became assistant employe relations manager at Esso headquarters a year ago, moving to New York from Bayonne, N. J., refinery where he was operations superintendent.

H. R. Sontag has been appointed plant manager, The Goodyear Tire & Rubber Co.'s Beaumont, Texas, chemical plant. **F. L. Barga** has been named personnel manager for the plant. Sontag has been with the company since 1941. Barga joined Goodyear in 1946 as manager of the Labor Department, St. Marys, Ohio, plant.

C. J. Livingstone has been appointed an associate director of research, Gulf Research & Development Co., in charge of product research, development and testing. Livingstone joined the Gulf company at Mellon Institute, Pittsburgh, after graduation from the University of Pittsburgh in 1924.

O. F. Van Beveren, vice president of American Overseas Petroleum Co., has been named president of the company. He succeeds **G. M. Cunningham,** who is retiring.

Dr. L. L. Ferstandig has been promoted from group supervisor to research



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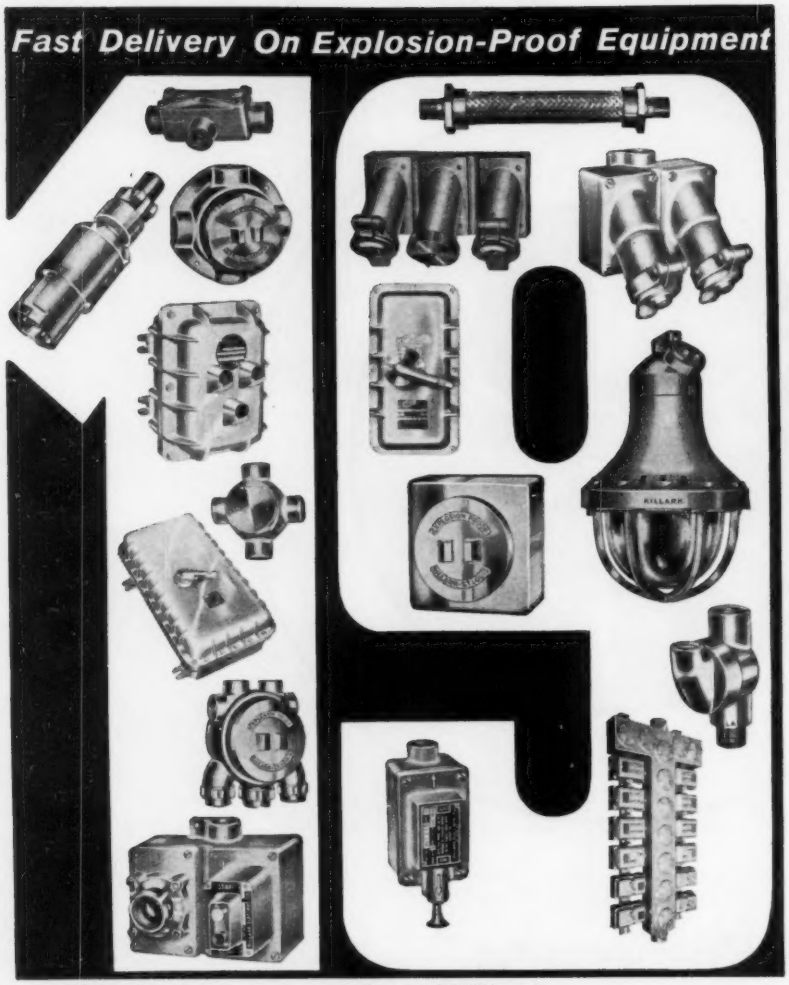

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Regardless of where you are located in the United States or Canada, there's a Killark warehouse nearby with a complete line of aluminum explosion-proof electrical fittings and fixtures, U.L. or C.S.A. approved. Your Killark wholesaler probably has the item you need in stock or can get it for you quickly because his stock is backed up by nearby factory warehouse stocks in nineteen locations to assure you fast delivery.

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Men . . .

associate in chemicals exploratory research, Richmond Laboratory, California Research Corp. Dr. Ferstandig, who joined Cal Research in 1950, received his Ph.D. in chemistry from Cornell University.

Robert F. Marschner has been elected chairman-elect, Division of Petroleum Chemistry, American Chemical Society. Dr. Marschner. who was elected at the fall meeting of the society in New York, is assistant director of information and communications, Research and Development Department, Standard Oil Co. (Indiana). In other ACS activities, he has been chairman, Council Committee on Publications, chairman, Chicago section of the society, and a member of the advisory boards of three ACS journals.

Marschner

Philip J. Byrne, Jr., has been named special assistant to management, Esso Research and Engineering Co., to help with the firm's continuing analysis of operations. Byrne joined Esso in 1927 at the affiliated Esso Research Laboratories in Baton Rouge, La.

A. J. Johnson, vice president, Development and Engineering Division, Shell Development Co.'s Emeryville, Calif., research center, has been elected vice president in the firm's home office, New York. **T. W. Evans,** vice president, research, will become vice president and general manager of the Emeryville research center.

Dr. Charles A. Thomas, chairman of the board of directors, Monsanto Chemical Co., has been awarded the honorary degree of doctor of laws by Lehigh University provost, **Dr. H. A. Neville.**

Clyde Port, Twin Cities Division general manager for Mobil Oil Co., has been named manager of employe relations with headquarters in New York. He will be in charge of employe relations for the company's operations in the United States and Canada.

E. F. Carlston has been promoted to research associate in chemical exploratory research, Richmond Laboratory, California Research Corp. He will conduct research in polymer chemistry seek-

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Motor Operated for Remote Control

CUT HIGH MAINTENANCE COST— Install WEDGEPLUGS

- **No Lubricants Required** for absolute control. Plug Lifts, Turns and Reseats in one quick, easy operation.
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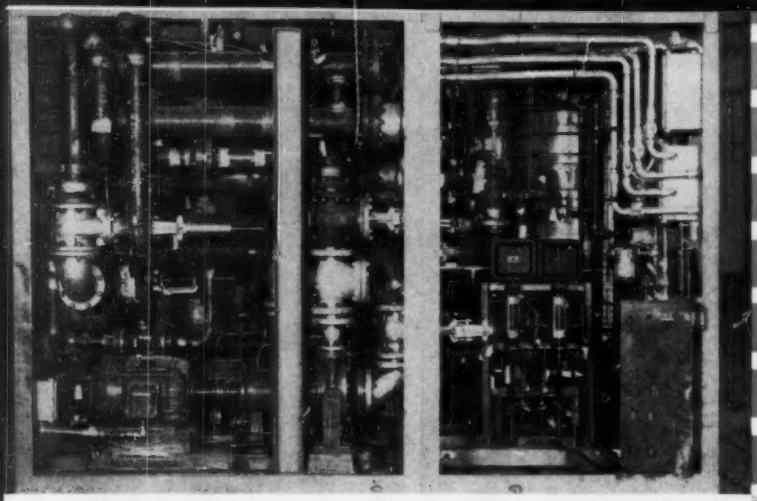
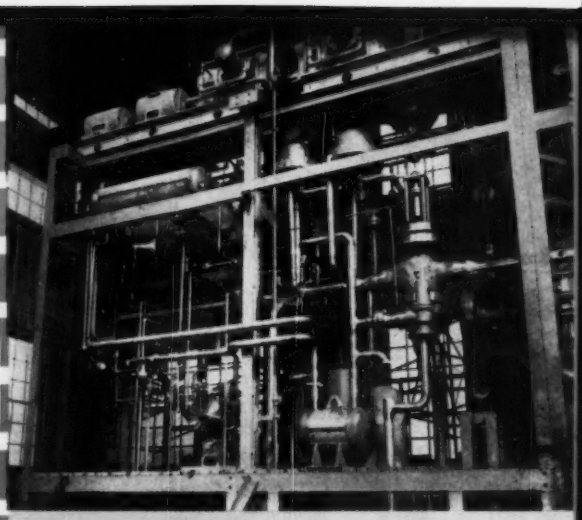
DESIGN ELIMINATES NEED FOR LUBRICATION



Shop view of package heating and cooling unit for nuclear testing, using Dowtherm as the heat transfer medium. It is installed in a radio-active location, with maximum precautions to insure trouble-free service.



Package units have been supplied for nuclear test facilities. Here is a shop assembled test loop to be installed in a nuclear reactor. The unit is designed to handle carbon dioxide gas to 1500°F and 550 PSIG, with some unique equipment designs for high temperature heating. Control panel and some accessory equipment not shown.

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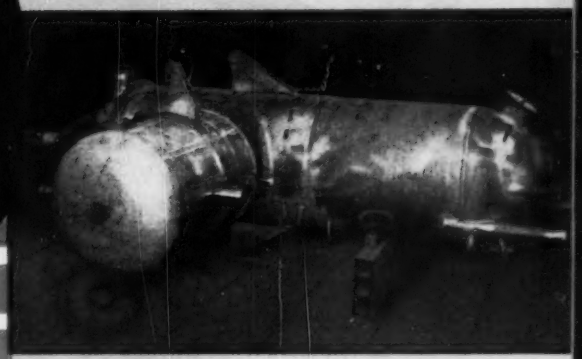
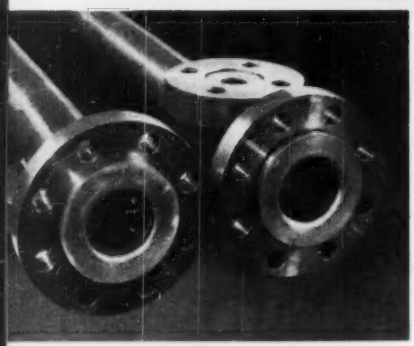
STRUTHERS WELLS

FOR NUCLEAR PLANTS, MISSILE FUELS AND HIGH TEMPERATURE PROCESSING

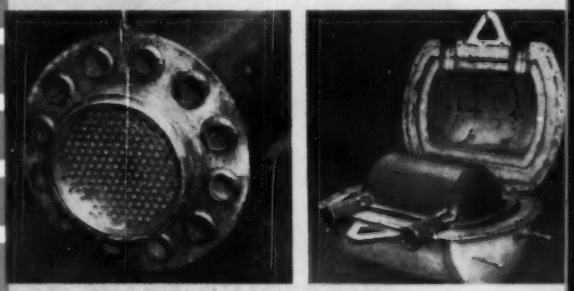


Fluid bed calciner for handling liquid nuclear wastes. Heat supplied by a Struthers Wells fired heater, using liquid metal as the transfer medium at 1500°F. Other liquid metal systems have been supplied for operations at 1800°F, with higher temperatures under consideration.



A portion of a silver lined job for special rocket fuel processing. A direct fired heater, exchanger and piping were supplied for operation at 1200°F.

Drain cooler for a boiling water reactor at a leading nuclear test facility; steam generators and other equipment were also supplied. Other nuclear equipment being handled includes the main sodium exchanger for a major reactor installation.



Special equipment designed for test loop shown in the photograph above. The unit on the left is constructed of Hastelloy X, with electric heating through indirect heat transfer medium.

For excellence in design and fabrication of any special processing equipment, take advantage of Struthers Wells unmatched facilities and experience.

Struthers Wells

STRUTHERS WELLS CORPORATION

PROCESS EQUIPMENT DIVISION — WARREN, PENNA.

Men . . .

ing new polymers and investigating their uses in the fields of plastics, surface coatings and fibers. He joined Cal Research in 1946.

Fraser H. Allen has been appointed chief engineer for Pan American Petroleum Corp. Allen, formerly division engineer for Pan American's Central Division, Oklahoma City, is a native of Toronto, Ont. A graduate of the University of Toronto, Allen also holds M.S. and Ph.D. degrees from The University of Texas, both in petroleum engineering. He joined Pan American in 1940.

Allen

Michael F. X. Gigliotti has been appointed assistant director of engineering for Monsanto Chemical Co.'s Plastics Division, Springfield, Mass., after serving as manager of product engineering there for the division.

George C. Love has been transferred from H. E. Bovay, Jr., Consulting Engineers, Houston office to the firm's Richland, Wash., office. Love replaces **Robert O. Grimes** as chief engineer. Grimes has taken back his former position as associate of the Bovay Houston organization, and has resumed his duties as senior project engineer.

J. W. Pitts has been promoted to supervisor, plant technical service section, Jefferson Chemical Co.'s Port Neches, Texas, plant. **W. H. Goff** succeeded Pitts as supervisor of the quality control section. Pitts joined Jefferson in 1950 as a chemist. Goff has been with Jefferson since 1954.

W. Lewis Perryman, Jr., executive vice president of General American Oil Co. of Texas, has been named president of the firm. He succeeds **Gordon Simpson,** who is retiring, but will continue as a director.

Russell E. Ritchie, vice president of Stone & Webster Service Corp., has been elected a director of the firm. Ritchie joined Stone & Webster in 1926 and was elected vice president in 1950.

R. M. Szymanski has been appointed manager, Bay Minette, Ala., plant of Newport Industries Co., a division of Heyden Newport Chemical Corp. Szy-

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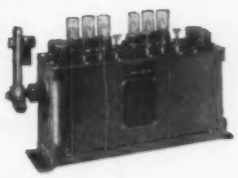

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SPECIALISTS IN LUBRICATORS AND METERING PUMPS SINCE 1898

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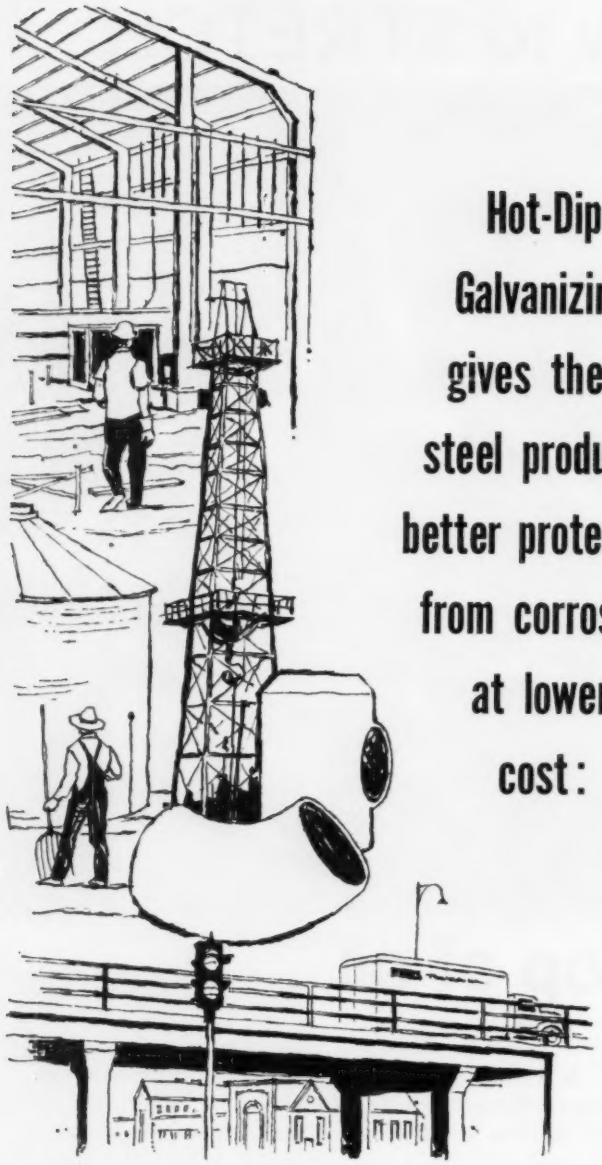
PROCESS EQUIPMENT DIVISION



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ONE OF THE SMITH INDUSTRIES

Men . . .

manski has engaged in chemical development, technical service and production activities for over 12 years. He joined Newport Industries in 1960 after prior experience with Olin-Mathieson Corp., E. I. du Pont de Nemours and Columbia National Corp.

William G. Shain has been appointed director of public relations, The Atlantic Refining Co. Shain, who joined Atlantic in 1946, will succeed **Richard Rollins,** who is retiring. Shain has served as industrial relations manager of the company's subsidiary in Brazil, and since 1954 has headed Atlantic's Foreign Personnel Division.

Shain

Dr. Rudolph L. Heider has been appointed an associate in the Development Department, Monsanto Chemical Co.'s Plastics Division. He has been serving as assistant director of research for that division.

Gregory J. Lynch has been named general manager, Australian Synthetic Rubber Co. He was employed by Atlantic Union Oil Co., Ltd., in 1930 after attending Sydney Technical College.

Dr. C. J. Egan has advanced from senior research chemist to research associate in physical chemistry, Richmond Laboratory, California Research Corp. Dr. Egan earned his Ph.D. from the University of California. He joined Cal Research in 1945.

C. E. Cunningham has been promoted to senior supervising engineer, Technical Division, Baytown, Texas, refinery, Humble Oil & Refining Co.'s Humble Division. He heads the electrical engineering section. Cunningham holds a B.S. degree in electrical engineering from Mississippi State University.

Jack L. Gogek has been appointed senior applications research chemist, Texas Butadiene & Chemical Corp.'s Miami, Fla., laboratories. Gogek was employed by Koppers Co. and previous to that he had experience with Shell Chemical Corp.

Ward A. Smith and Dr. James M. Willis received certificates for the outstanding paper presented at the spring meeting, Rubber Chemistry Division,

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IN WOVEN WIRE SCREEN AND WIRE CLOTH PRODUCTS

Whether you are grinding, sizing, scalping, dewatering or filtering it's the accuracy of the "working opening" that makes the difference in woven wire screen and wire cloth products. We pride ourselves in weaving accurate "working openings", an engineered screening surface to meet your specification.

First, the best metal or alloy is selected—hard enough to withstand the abrasive action—ductile enough not to break under stress. Next, the best wire diameter and crimp are determined. Then we weave wire screen or wire cloth around accurate "working openings" best suited for your screening application.

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When you buy a Fast's coupling, you can bet your bottom dollar everything was built on the spot, not assembled piece by piece from other suppliers. Koppers multi-million dollar manufacturing facilities are the most modern in the industry . . . with advanced program machines, highly accurate gear shapers, a complete forge shop.

For example, all Fast's Couplings are jig-drilled and jig-reamed for greater interchangeability of parts. Result: you get high-quality, smooth-running, long-lived units that are the choice of more equipment manufacturers than any other gear-type coupling.
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FAST'S COUPLINGS

Engineered Products Sold with Service

Men . . .

American Chemical Society in Buffalo, N. Y. Both men are with The Firestone Tire & Rubber Co.'s research staff. Smith reported on the compounding and testing of Firestone's synthetic rubber extender.

Burton C. Clarkson has been named manager, Baltimore refinery, Humble Oil & Refining Co.'s Esso Standard Division. He succeeds **Charles C. Swoope,** who will serve as a consultant pending retirement. Clarkson has been assistant manager of the Baltimore plant since July 1. He went to Baltimore from Esso's Bayway refinery, Linden, N. J., where he was assistant head of chemical products operations. He joined Esso at Bayway in 1950, held process and mechanical engineering posts, and was assigned to the Chemical Products Department as a unit supervisor in 1955. Clarkson became a division head in 1958 and assistant department head shortly before his transfer to Baltimore.

Clarkson

Richard J. Binder has joined the Engineering Department, Monsanto Chemical Co.'s Inorganic Chemicals Division at St. Louis, after serving with Geo. E. Wells, Inc.

W. C. Behrmann and R. A. Tynes have joined the technical staff, Esso Research and Laboratories, Baton Rouge, La. **E. M. Charlet,** on the technical staff of Esso Research Laboratories, has accepted a rotational assignment at Esso Research, Ltd., Abingdon, England.

Paul Kimbrell Smith, Jr., has joined the Natural Gasoline Department, Kerr-McGee Oil Industries, Inc., as staff engineer. Smith, formerly plant foreman for Mobil Oil Co., at Smackover, Ark., is a graduate of Louisiana Tech, Ruston, where he received his B.S. degree in petroleum engineering in 1954.

Dr. C. Hunter Montgomery has joined the Houston office medical staff, Humble Division, Humble Oil & Refining Co. Dr. Montgomery succeeds **Dr. Harvey B. Snyder,** who has joined the medical staff, Standard Oil Co. (New Jersey) in New York City.

E. N. Cart, P. H. McGinnis, Jr., A. H. Wehe, Jr., R. A. Stanfield, and **W. J. Hatcher, Jr.,** have joined the tech-

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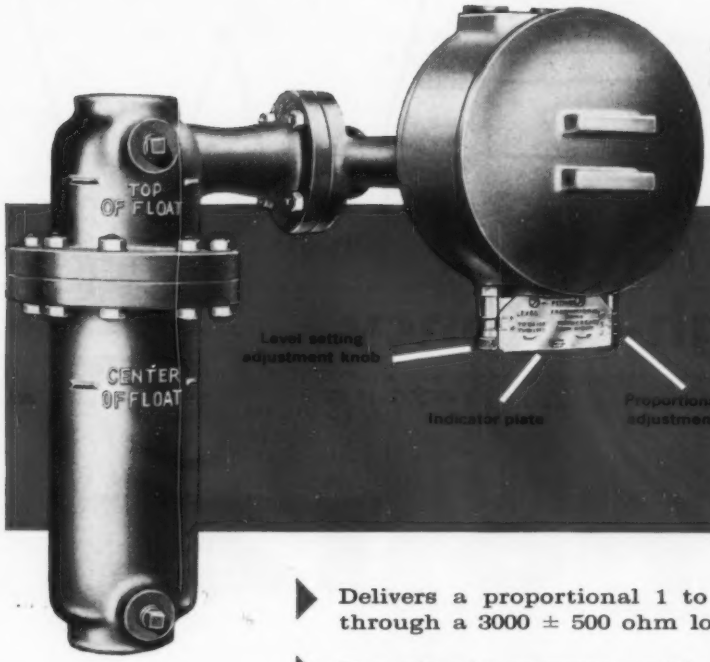
FOR ELECTRONIC SYSTEMS

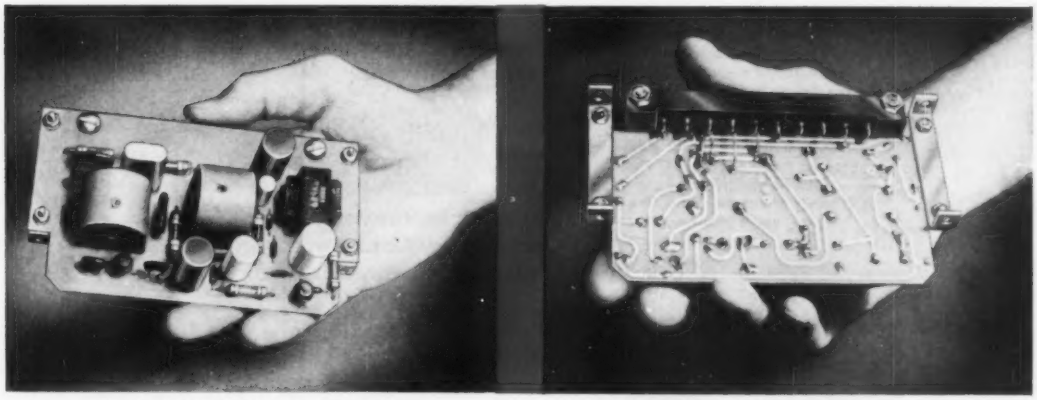


Quick accurate external adjustment

- **Delivers a proportional 1 to 5 milliampere dc signal through a 3000 ± 500 ohm load.**
- **Has plug-in converter with printed circuit. Conventional leads and unnecessary wiring are eliminated.**

This Fisher explosion-proof Electronic Level-Trol features external adjustment for proportional band and liquid level height, and incorporates extreme simplicity of design throughout. Silicon transistors and diodes are used instead of the conventional vacuum tubes. You do not need any additional parts to reverse action of the unit. With only .25% effect from ±15% supply voltage change, line voltage fluctuation is of negligible effect.

Fisher Bulletin F-85 will give you complete details on the Fisher Type 2300 Electronic Level-Trol. Send for it.



Plug-in electronic converter assembly.

Printed circuit of the converter assembly.

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WHERE RESEARCH TODAY MEANS PROGRESS TOMORROW

Men . . .

nical staff, Esso Research Laboratories, Baton Rouge, La. **W. M. Metrailer** has been named a research associate at the laboratories.

George O. Relf, Jr., has been elected an administrative vice president, Gulf Oil Corp. Relf will succeed **Newby C. Simpson** as coordinator of the Production Department. Relf joined Gulf in 1937.

Roland A. Beck has been appointed director of the Montebello, Calif., Research Laboratory, Texaco, Inc. Beck, who holds numerous patents in the field of petroleum research, succeeds the late **du Bois Eastman** as head of the Montebello Laboratory. Upon joining Texaco as a chemist in 1941, Beck was assigned to the Fuels Research Department at the Texaco research center, Beacon, N. Y., where he was promoted to project leader, fuels Research in 1947. He was transferred to Montebello in 1949 and the following year became supervisor of experimental operations there.

Beck

Erwin G. Somogyi has been elected a vice president of Monsanto Chemical Co. and appointed general manager of the company's Research & Engineering Division, after serving as research director, Inorganic Chemicals Division, St. Louis.

Millard E. Stone has been named vice president, employe and community relations, Sinclair Oil Co. He will direct enlarged management development and personnel coordination for Sinclair companies.

W. A. Raatz has been promoted from group supervisor to supervising research engineer, process planning section, Richmond Laboratory, California Research Corp.

Howard K. Nason has been elected president, Monsanto Research Corp., a wholly owned subsidiary of Monsanto Chemical Co., after serving as a Monsanto vice president and general manager of the company's Research & Engineering Division at St. Louis.

John M. Sprague has become Washington representative for Humble Oil & Refining Co. Sprague had been deputy assistant secretary and comptroller, U.S. Defense Department. He was regional vice president, Carter Oil Co., Tulsa, before beginning his hitch with the U.S. Government.

Stanley B. Mirviss and Samuel B. Robison have been named research associates, Esso Research and Engineering Co. Mirviss joined Esso Research in 1950. Robison joined the company in 1943.

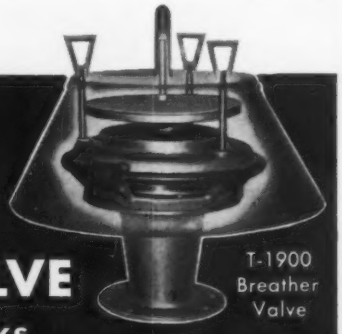
Fred B. Korsmeyer has become manager, Corporate Employe Relations Department, Socony Mobil Oil Co., Inc.

Dr. E. W. Gardiner has been appointed senior research coordinator, Petroleum Products Department, California Research Corp., San Francisco.

Dean Arthur Young has been promoted to senior research chemist, Union Research Center, Brea, Calif.

Richard K. Flitcraft has been appointed research director, Monsanto Chemical Co.'s Inorganic Chemicals Division, St. Louis, after serving as product director of detergents and heavy chemicals for the division there.

NEW
Wheaton
BREATHER VALVE
gives storage tanks
MAXIMUM FLOW and
MINIMUM VAPOR LOSS



T-1900 Breather Valve

This new Wheaton Type T-1900 "Quality Built" Breather Valve is thoroughly lab-tested and field tested for high flow rate and vapor tight control of vacuum and pressure.

Big advantages include diaphragms for both pressure and vacuum pallets . . . anodized aluminum bodies . . . large areas of flow spaces . . . easy inspection and maintenance.

The Wheaton Type T-1900 Breather Valve can help *your* storage tank operation. Send for details now.

GET TIGHT, PRECISION EMERGENCY VENTING

For emergency venting of storage tanks, use the *Wheaton Type T-1950 Emergency Vent and Manhole Cover.* As required in A. P. I. Venting Guide, a diaphragm seal in cover assures positive seating.

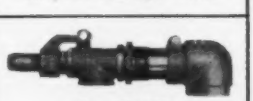
WHEATON BRASS WORKS, UNION, N. J.

Manufacturers of Loading Arm Assemblies, Swing Joints, Loading Valves, Storage Tank Fittings and Truck Tank Equipment for the Petroleum and Chemical Industries.

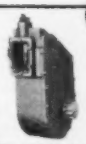
Foreign Manufacturers

Emco Ltd., London, Ontario, Canada • Emco Brass Mfg. Co. Ltd., Margate, Kent, England
Emco G.M.B.H., Allendorf, Germany • Ljungmans, Malmo, Sweden
Baza S.R.L., Buenos Aires, Argentina, S.A.
Worthington Corporation, Rio De Janeiro, Brazil, S.A.

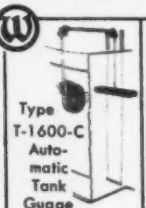
Install WHEATON fittings on your storage tanks



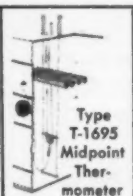
Type T-1550 Water Drain Valve



Type T-1600 Automatic Tank Gauge



Type T-1600-C Automatic Tank Guage



Type T-1695 Midpoint Thermometer

Type T-1700 Gauge Hatch

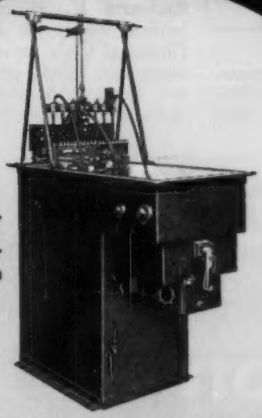
For more data on advertised products, use Readers' Service Cards, last page.

EC&M's LINE OF HIGH VOLTAGE STARTERS GIVES YOU

*EXACTLY the Right Starter for Any Location!**

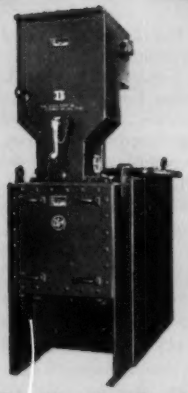
* Hazardous Location, Class I, Group D, Divisions 1 and 2

TOTALLY OIL-IMMERSED



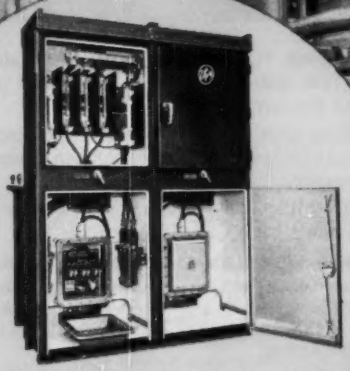
Type AT Combination Starter shown with Contactor and Overload Panel raised above the oil level without disconnecting any bolts or leads—in NEMA 3R enclosure for outdoor mounting, available in 50,000 KVA (certified) interrupting capacity.

OIL-IMMERSED



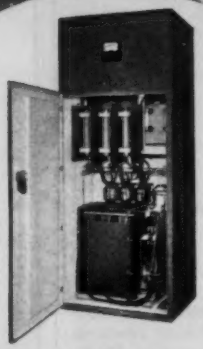
Type AM Combination Starter in NEMA 3R enclosure for indoor or outdoor locations—available in 50,000 KVA (certified) interrupting capacity —and VALIMITOR.®

OIL-BREAK



Type AH Combination Starter in NEMA 1 or 3R enclosures for indoor, outdoor or pressurized control room—available in 3 interrupting ratings, 50,000 KVA—POWER FUSED—and VALIMITOR.®

AIR-BREAK



Type AFG Combination Starter for Pressurized Control Rooms. Built in Class E1, Class E2 and VALIMITOR.®

For complete information write for Bulletin 8131-L

SQUARE D COMPANY

EC&M DIVISION • CLEVELAND 28, OHIO

wherever electricity is distributed and controlled

7928-R

Men . . .

John R. Ingram has been appointed manager of Standard-Vacuum Oil Co.'s Lubricating & Special Products Supply Department. Ingram joined Standard-Vacuum upon its formation in 1933, following three years' service with Socony Mobil Oil Co. in New York City. He filled several positions in lubricating and special products supply, becoming assistant products purchasing manager in 1948.

Ingram

Dr. Clayton F. Callis has been appointed an assistant director, Research Department, Monsanto Chemical Co.'s Inorganic Chemicals Division, St. Louis, after serving as a senior group leader in that department.

S. A. Fruchtman has been appointed chief engineer, Crawford & Russell, Inc., engineering and construction firm. Fruchtman has been chief design engineer with the company for several years. He graduated from City College of New York with a B.S. degree in chemical engineering and later received his M. S. degree from New York University. Before joining Crawford & Russell, he was with Foster Wheeler Corp. as a project manager.

Fruchtman

— Deaths —

William F. Lyte, 59, vice president of Douglas Oil Co. of California and general manager of United Asphalt Co., died October 9, while traveling in Europe. He was a resident of San Marino, Calif. Lyte had been with Douglas Oil for the past 13 years. Prior to that, he was president of Bell Oil and Refining Sales Co.

John A. Ritter, 73, long-time official in Sun Oil Co.'s Southwest Division, died October 1 after a long illness. Ritter, who retired in 1954 after 31 years with Sun, was general operating superintendent for the Southwest Division for more than 13 years.

Where control depends on measurement!
CON-O-PAK THERMOCOUPLES
FROM -300°F TO 4000° PLUS
The world's finest thermocouples. New process increases precision and temperature range. Exceeds all military and commercial specs. Con-O-Pak is used in aircraft, missiles, nucleonics, chemical processing.
Useful data? . . . Ask for "The Con-O-Pak Story."
CON-O-PAK
CONTINENTAL SENSING INC.
1950 N. Ruby St., Melrose Park, Illinois

FLEXIBLE AND SHEATHED THERMOCOUPLES • THERMOCOUPLE WIRE • HEATING ELEMENTS • CONNECTORS

VOSS VALVES will mean LESS MAINTENANCE FEWER SHUTDOWNS for your COMPRESSORS

Voss Valves are made to specification, machined from solid stock (not cast)—using best alloy steels; for corrosion condition—stainless steels, such as 410, 18-8 or non-ferrous alloys—monel, inconel, etc. Plates are machined (not stamped) and ground for precise close tolerance fit; are dimensionally stable . . . ductile . . . resist fracture, high temperatures and corrosion . . . withstand fatigue. Springs of heavy rectangular sections and large diameters add to dependability and safety.

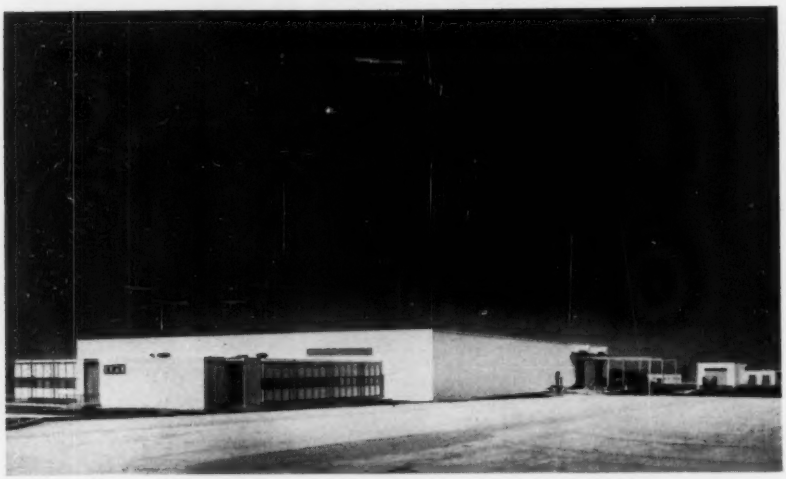
- up to 40% more valve area
- minimum pressure loss
- higher efficiency
- less power consumption
- normal discharge temperature
- quiet, vibration-free
- utmost safety
- lower operating costs

For detailed proposal send name, bore, stroke and speed of machine.

J. H. H. VOSS VALVES REG. U.S. PAT. OFF.
J. H. H. VOSS Co., Inc.
785 East 144th Street, New York 54, N. Y.

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers Notes...



A modern industrial plant with 77,000 square feet of floor space has been completed by Warner Lewis Co. in Tulsa. Warner Lewis, a division of Fram Corp., manufactures separators and filters. The firm has moved all its manufacturing equipment and office facilities to this new location at 2929 E. Apache St. from 817 N. Lewis Place, Tulsa.

FLUOR PRODUCTS CO., a division of The Fluor Corp., Ltd., has named **Robert W. Kerr** president. Kerr was also elected vice president and a member of Fluor's board of directors. He resigned as president and director of Fairbanks, Morse & Co. to accept the position with Fluor. He will head Fluor Products' diversified operations, including the manufacture of industrial cooling towers and air conditioning towers. He graduated from the University of California.

Kerr

HAVEG INDUSTRIES, INC., has elected **Thomas F. Anderson,** vice president. Anderson joined Haveg in 1952 as a chief chemist. He has been director of research and development since 1958. He has worked with the National Defense Research Committee, Libbey-Owens-Ford Glass Co., and the Rohm & Haas Co., Redstone Arsenal Research Division.

INGERSOLL-RAND CO.'s Centrifugal Pump Division has named **R. J. Bunch** manager. **G. T. Jones** has been appointed manager, Condenser Department, and **T. E. Bennett** has been promoted to manager, Engineering Pump Department.

CONSOLIDATED ALUMINUM CORP., Jackson, Tenn., has elected **William D. Miller** executive vice president. Miller, also named a director of the firm, joined Consolidated Aluminum last March as a vice president. He was formerly vice president, Continental Copper and Steel Industries, Inc.

BENDIX CORP.'s Bendix Filter Division has appointed **Frederick S. Detwiler** sales engineer for the West Coast branch office. During the last five years, Detwiler has worked exclusively in the field of fluid filtration.

HAGAN CHEMICALS & CONTROLS, INC., has appointed **Donald T. Cusack** manager, sales-process industries. He will specialize in the sale of Hagan controls to the chemical, petrochemical and petroleum industries. Cusack was previously with Fischer and Porter Co., New York, as sales engineer, district sales manager, and Eastern regional sales manager. He graduated from Stevens Institute of Technology, and obtained a master of science degree from New York University.

Cusack

LEE RUBBER & TIRE CORP. has appointed **Norris B. Green** Southwest district manager, Republic Rubber Division. Green, who will headquarter in Houston, will supervise operations of Republic's field representatives in the Southwest trading area.

COMBUSTION ENGINEERING CO. has moved its offices to the John Plain Building, 427 West Randolph St., Chicago. The office will be headquarters for the engineering, sales and service departments.

SCOVILL MANUFACTURING CO. has purchased the assets of International Couplings, Inc., a division of The Gabriel Co. Products formerly manufactured by International Couplings will be consolidated with Scovill's line of industrial couplings and sold by Scovill's sales force.

DRESSER INDUSTRIES, INC.'s, board of directors has approved the purchase of Podbielniak, Inc., a Chicago manufacturer of centrifugal solvent extractors, laboratory fractional distillation apparatus and packaged distillation plants.

SCIENTIFIC AND PROCESS INSTRUMENTS DIVISION, Beckman Instruments, Inc., has appointed **Thomas A. Guerin** product line manager for electrochemical, hygrometer, amplifier and leak detector product lines. Guerin, who was a field sales engineer for Beckman prior to his new appointment, has been with the firm since 1956.

ROCKWELL MANUFACTURING CO. has named **Harry W. Fisher** manager, central liquid meter products engineering. Fisher will be responsible for all headquarters engineering activities relating to the company's petroleum, industrial and water meter products. He joined Rockwell in 1952 as a mechanical engineer.

ORONITE CHEMICAL CO. and California Chemical Co.'s New York market research and development group have moved their offices from 30 Rockefeller Plaza to One Rockefeller Plaza, New York City.

ALLIS-CHALMERS MANUFACTURING CO. has appointed **Walter W. Edens** assistant director, Research Division. He had been supervisor of metallurgical research. Edens joined Allis-Chalmers in 1952 as a supervisor of melting and foundry research.

COOPER-BESSEMER CORP. has named **O. W. Stanley** branch manager, Odessa, Texas, branch office. He will direct field sales and service activities in the West Texas area. Stanley was a sales engineer in the company's Houston office. He fills the post vacated by **C. L. McDougall,** who has been appointed assistant parts sales manager of the firm at company headquarters, Mount Vernon, Ohio.

Stanley

Why, indeed? As long as you're in a hydrogen area, there's just as much danger of explosion with one piece of equipment as there is with the other.

And the same goes for acetylene areas, too. *And* for all other pieces of electrical equipment in such an area . . . fixture hangers, seals, flexible couplings, junctions, push button stations.

Crouse-Hinds is the only single source for complete systems of UL-listed explosion-proof electrical equipment, no matter what the National Electrical Code Class or Group.

Crouse-Hinds is also your prime source for expert assistance in choosing and applying equipment for hazardous areas. A Crouse-Hinds Field Engineer is always available to help you plan complete protection in flammable atmospheres of gases, vapors or dusts.

Call your Crouse-Hinds Distributor while you're still in the planning stage of building or remodeling. *That's* the time he can really save you money!

**National Electrical Code designations*

CROUSE HINDS
SYRACUSE NEW YORK

OFFICES: Atlanta Baton Rouge Birmingham Boston Buffalo Charlotte Chicago Cincinnati Cleveland Corpus Christi Dallas Denver Detroit Houston Indianapolis Kansas City Los Angeles Milwaukee New Orleans New York Omaha Philadelphia Pittsburgh Portland, Ore. St. Louis St. Paul Salt Lake City San Francisco Seattle Tulsa Washington
RESIDENT REPRESENTATIVES: Albany Baltimore Reading, Pa. Richmond, Va.
Crouse-Hinds of Canada, Ltd., Toronto, Ont. Crouse-Hinds-Domex, S. A. de C. V. Mexico City, D. F. Peterco, Sao Paulo, Brazil

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a NEW approach to flow control

"FLOW TESTED"

Uniflow

BAR STOCK AIR OPERATED
CONTROL VALVES

In sizes ¼" to 1" with body ratings to 15,000 psi in steel, 15,000 psi in stainless and 800 psi in brass. Straight-through or Angle Type valve bodies. 3-15 psi, Air to open—Air to close.

- Flow Co-efficient: Cv. .00001 to Cv. 3.0 with Linear Plug and removable seat are standard construction.
- Parabolic & equal % plugs Cv 0.55 to Cv 6.0
- Complete design features to meet your specifications.
- For special applications—body and trim material can be furnished in Monel, Aluminum, and Hastelloy "C"
- Optional features available: Bellows Seal, Cooling Fins, Top Mounted Moore Valve Positioners, Weld end Bodies and Side Mounted Foxboro Positioners.

Write for Bulletin No. 116.

Uniflow Valve Corporation
30 QUINE ST., CRANFORD, NEW JERSEY • BRidge 6-8300

New...

Davis Paramagnetic **OXYGEN** Analyzer

MODEL 11-4500

1. Selective to oxygen. Measures oxygen content of gases.
2. Simple non-electronic circuit.
3. Rugged glass-coated, corrosion-resistant filaments in plastic measurement cell, with constant temperature housing.
4. Fast response—95% reading in 15 seconds.
5. Simple pressure compensation.
6. Available in:
   a) Standard or explosion-proof construction.
   b) Five-inch scale indicating meter. Alarm contact and relay optional, also conventional electronic recorder controllers.
   c) Floor standing cubicle or panel-mounted cabinets.
7. Ranges from 0 — 5% O_2 to 0 — 100% O_2.

INSTRUMENT DAVIS DIVISION

DAVIS INSTRUMENTS
Division of Davis Emergency Equipment Co., Inc.
164 Halleck Street, Newark 4, N. J.
In Canada: Levitt Safety Ltd., 747 Vaughan Road, Toronto

Suppliers . . .

ARMSTRONG CORK CO. has appointed **Ralph M. Hill** manager, Urethane and Fluorocarbon Sales Department. **J. A.**

Hill

Kelly

Kelly was named technical assistant and will be responsible for the promotion of cast urethanes. Hill formerly headed the Friction Materials Department.

BENDIX FILTER DIVISION, Bendix Corp., has named **Edward C. McFadden** sales engineer in the middle Atlantic states. McFadden opens a new office at 607 Washington St., Reading, Pa., to service users of all types of fluid filters in New York, New Jersey, Pennsylvania, Maryland, West Virginia, Delaware, North Carolina and South Carolina. He was formerly a sales engineer for Bendix Filter Division, West Coast branch.

McFadden

FAIRBANKS, MORSE & CO. has appointed **Eugene R. Carroll** resident sales representative, Charleston, W. Va. Carroll, a mechanical engineering graduate of the University of Colorado, has been assigned to Charleston from the firm's Cincinnati sales branch.

ELION INSTRUMENTS, INC. has named **Richard A. Denton** vice president, High Vacuum Division. Denton became general manager, Vacuum Equipment Division, New York Air Brake Co., in 1956.

OWATONNA TOOL CO. has appointed **John Hann** and **Robert Wilkinson** district sales managers for the Oregon, Washington and Northern California territory.

PARKER SEAL CO. has promoted **William Swan** to assistant sales manager. He was formerly the Parker Seal sales representative covering Dayton, Ohio, and the surrounding area.

MINNEAPOLIS-HONEYWELL REGULATOR CO.'s Micro Switch Division has named **John K. Lincoln,** former Eastern Division sales manager, sales manager. He suc-

For more data on advertised products, use Readers' Service Cards, last page.

Ranges: 0-20 to 0-200 inches at static pressures to 2000 psi.

new Foxboro Flow Transmitter continues to indicate even without air supply...needs no mercury

Here's a new indicating flow transmitter with safety built right in! Measurement indication is continuous — even if air supply fails.

Moreover, the M/45 Flow Transmitter uses no mercury in its measuring system. Instead, it uses the Foxboro Type 37 diaphragm bellows unit, which responds to differential pressure changes with unmatched sensitivity. And it cannot be damaged by overrange.

Over all accuracy is guaranteed at ±½ of 1%; ambient temperature stability at better than ½ of 1% in 50°F temperature change. Servicing is simple — zero drift virtually non-existent.

The M/45 Transmitter is also available for temperature, pressure, liquid level and dew point.

Ask your Foxboro Field Engineer for complete details, or write for Bulletin 13-30. The M/45's unmatched sensitivity — its low maintenance — make it well worth your consideration. The Foxboro Company, 7411 Neponset Ave., Foxboro, Massachusetts.

FOXBORO
REG. U.S. PAT. OFF.

For more data on advertised products, use Readers' Service Cards, last page.

New B&W REFRACTORIES FOR THE PETROCHEMICAL INDUSTRY

B&W's line of refractories has been enlarged by the addition of new heavy duty firebrick and new ramming mixes. These new products, now offered after many years of developmental and field experience, are specifically designed for superior service in carbon black furnaces, butadiene reactors, reforming furnaces and vessels and other typical equipment used in petrochemical processing.

FIREBRICK

★

KAO-HB

HIGH BURNED SUPER DUTY FIREBRICK

Fusion point 3220 F. This brick offers an excellent balance of properties to assure superior service. It provides approximately 5% more alumina content and lower total impurities than competitive brick. It has excellent spalling resistance.

KAO 60

60% ALUMINA FIREBRICK

Fusion point 3250 F. Provides higher hot load strength than any competitive brick. Spalling loss is only 1%

KAO 70

70% ALUMINA FIREBRICK

Very low total impurities provide long life. Spall loss of only 2%.

RAMMING MIXES

★

MULRAM E

USE LIMIT 3200F
ALUMINA CONTENT–80%

This new ramming mix with extremely low permeability provides exceptional resistance to slag or molten metal penetration. High strength provides good erosion resistance.

MULRAM EF

USE LIMIT 3100F
ALUMINA CONTENT–80%

Similar to Mulram E but supplied in finer grain.

FOR COMPLETE PROPERTIES SHEETS and additional information on these new B&W Refractories products, write to The Babcock & Wilcox Company, Refractories Division, 161 East 42nd Street, New York 17, N. Y.

B&W

R 687 C

B&W THE BABCOCK & WILCOX COMPANY

REFRACTORIES DIVISION

B&W Firebrick, Insulating Firebrick, and Refractory Castables, Plastics, Ramming Mixes, Mortars, and Ceramic Fiber.

Suppliers . . .

ceeds **Frank Wilsy** who was recently promoted to vice president. **Richard F. Johnson** has been appointed central area sales manager, Cleveland, Ohio, succeeding **Kenneth J. Cumming.** In turn, Cumming has been promoted to sales manager, Minneapolis-Honeywell's Marion Instrument Division, Manchester, N.H.

TIMKEN ROLLER BEARING CO. has elected **R. L. Frederick** a vice president in charge of international divisions. **R. A. Gulling,** the company's assistant treasurer,

Frederick

Gulling

has been appointed controller. Frederick, formerly executive director, international divisions, joined Timken in 1940. Gulling came to the firm in 1943.

SCIENTIFIC AND PROCESS INSTRUMENTS DIVISION, Beckman Instruments, Inc., has named **William S. Bierbaum** product line manager. Bierbaum will be responsible for sales of process and laboratory gas chromatographs and flame ionization analyzers. He joined the firm in 1957 as a field sales engineer in the Mountainside, N. J., office.

J. I. CASE CO. has appointed **T. J. Garbeff** manager, Central Parts Division. Garbeff joined the company in 1949. He previously was with Nordberg Manufacturing Co.

WALWORTH CO. has appointed **Clyde W. Cook** vice president of sales, Lubricated Plug Valve Division. Cook, joined Grove Valve and Regulator Co., now a Walworth subsidiary, as a sales engineer in Texas in 1954. In 1958, he was named Western Division sales manager of Grove, the position he held until his present appointment.

Cook

MARCUS TRANSFORMER CO. has named **Daniel A. Thorn,** president of Industrial-Workmen's Savings & Loan Association, to the board of directors.

CONTINENTAL-EMSCO CO.'s Industrial Sales Division has added five companies to distribute its line of swivel joints and load-

Matheson Corrosion Resistant Pressure Regulators

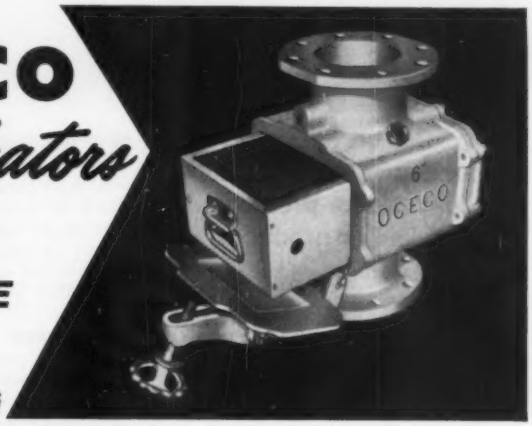
Series 15 for Hydrogen Chloride, Boron Trifluoride, Chlorine, and other corrosive gases or gas mixtures.

Series 15 regulators use the most chemically resistant materials for greatly increased life and performance. A special nickel coating is used on all body surfaces. The seat is of long wearing, inert Kel-F; all gaskets are of Teflon. The flow control outlet valve is Monel. A monel check valve to prevent suck-back is available for direct attachment. See the Matheson Compressed Gas Catalog for information on other Matheson regulators and valves designed for Sulfur Dioxide, Hydrogen Sulfide, Ammonia and the other 82 Matheson Gases. Write for your free copy.

The Matheson Company, Inc.

Compressed Gases and Regulators
East Rutherford, N. J.; Joliet, Ill.; Newark, Calif.

OCECO *Dehydrators*



PREVENT MOISTURE FROM ENTERING YOUR TANKS

Oceco Dehydrators remove the water vapor from air breathed into your tanks when product is being pumped out, preventing dilution. Sturdy, gas-tight unit mounts on the tank roof. The desiccant material that traps the moisture is held in a wire mesh drawer and can be re-activated or replaced easily. Proven in service. 2″, 3″, 4″, 6″, 8″, 10″ and 12″ sizes. Get full details.

Write for Bulletin No. 500-5-0 Today!

THE JOHNSTON & JENNINGS CO.

4710 West Division Street • Chicago 51, Illinois

***division of* PETTIBONE MULLIKEN CORPORATION**

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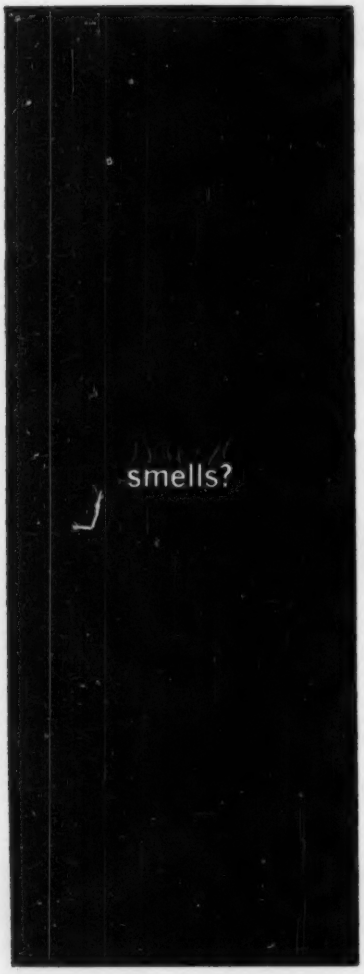

Call on Rhodia "Odor Engineering" to solve your malodor problems in plant or product

Rhodia Inc. is the world leader in industrial odor control and reodorization technology and a primary producer of industrial aromatic chemicals. It offers fully qualified consultation service anywhere in the United States without cost or obligation.

RHODIA INC., 32-8
60 East 56 St., New York 22, New York
Gentlemen:
Please send me Rhodia literature.
My problem is: (please give specifics)

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NAME_____

ADDRESS_____

CITY_____ STATE_____

RHODIA INC.
60 East 56 St., New York 22, New York
(Phone: PLaza 3-4850)

Suppliers . . .

ing arms. The new distributors are: Gary Sales Co., Detroit; Midway Supply Co., Inc., Jackson, Mich.; Mechanical and Electrical Equipment Co., Tulsa; Calvert-Conel Co., Cleveland, Ohio, and Keystone Pipe and Supply Co., Milwaukee.

CHAIN BELT CO. has appointed **G. H. Pfeifer** director of product merchandising and public relations. **Robert F. Olson** has been named sales promotion manager of

Pfeifer

Olson

the industrial section. Pfeifer had been serving as Chain Belt's manager of sales promotion and advertising since 1955. Olson joined the company in 1948 in the Shafer Bearing Division.

J. I. CASE CO. has appointed **Carl von Linsowe** director of engineering, industrial products. For the past three years, von Linsowe has been manager of engineering, Churrbusco, Ind., works. Before joining Case, he was with the Allison Division, General Motors Corp.

WORTHINGTON CORP.'s Annin Co. Division has appointed **Charles L. Bates** general sales manager. Bates comes to Annin from Mason-Neilan, Norwood, Mass., also a division of Worthington Corp., where he was sales engineer for special engineering applications and educational programs.

H. K. PORTER CO., INC., has named **Gene P. Robers** general sales manager, Thermoid Division. Before joining Thermoid, Robers was a vice president, Carter Carburetor Division of ACF Industries.

HAGAN CHEMICALS & CONTROLS, INC., has appointed **John P. Kleber** manager, Water Chemical Sales Division. Kleber had been manager of the firm's Municipal and Process Waters Department since 1949. He joined Hagan Chemicals in 1940.

FIBREBOARD PAPER PRODUCTS CORP. has named **Beat J. Jenni** manager Boise, Idaho, sales district. He had been a sales representative with the company in the Northwest.

ATLAS VALVE CO. has appointed Heat & Power Equipment Co., Charlotte, N. C., a sales representative. Heat & Power

Interested personal service--
always—
when you buy from Eastman

Eastman Gasoline Additives

Tenamene 1
An aminophenol. Low cost, efficient gum inhibitor for motor fuel.

Tenamene 2
A phenylenediamine. A versatile gum inhibitor for motor fuels and aviation gasolines. Also acts as a sweetening agent in many catalytically cracked stocks.

Tenamene 3
An alkylated phenol. Efficient gum inhibitor for motor fuels, aviation gasolines and jet fuels.

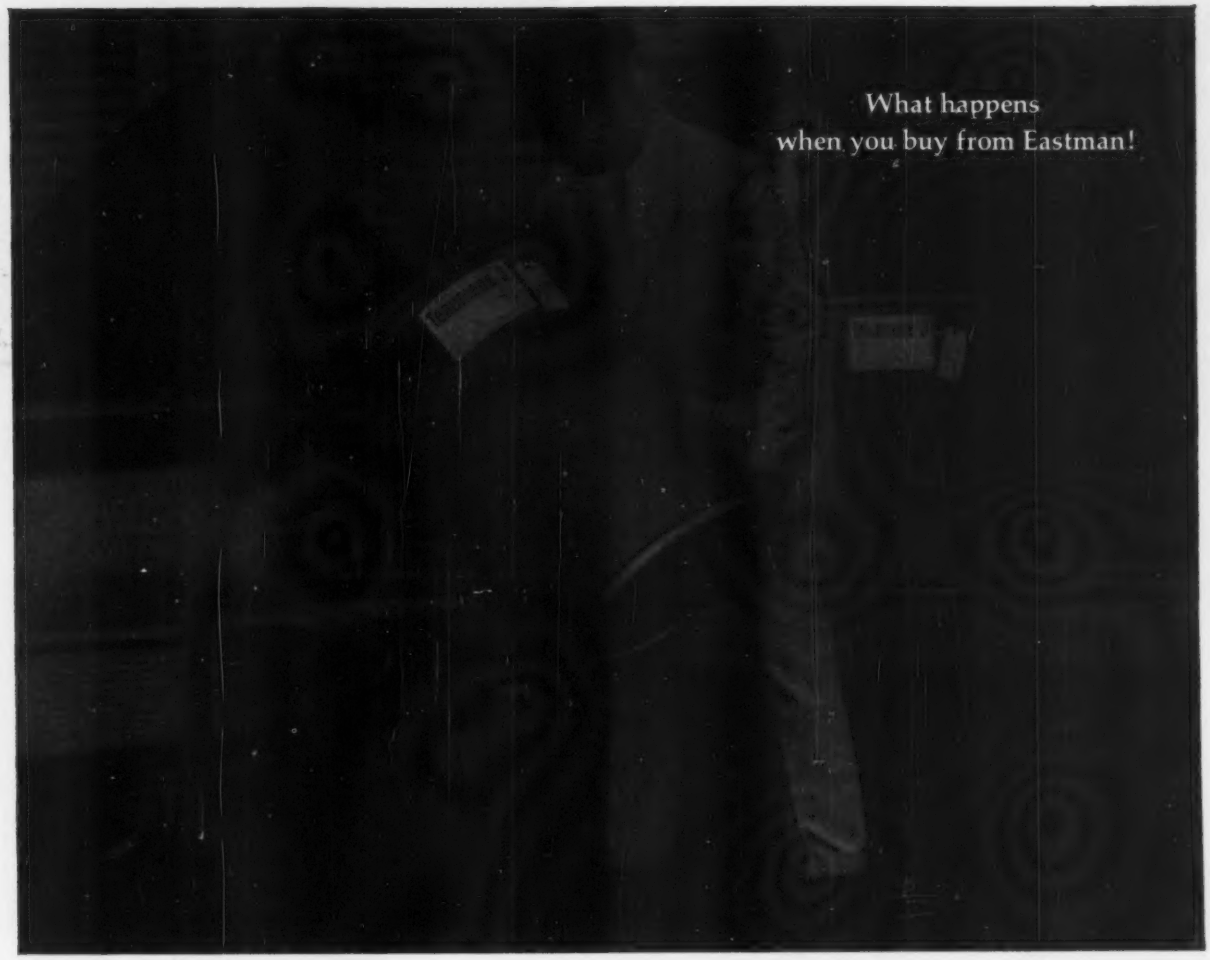
Tenamene 60
A powerful copper deactivator.

Tenamene MD 50
A freeze-resistant solution containing copper deactivator.

For information on how to use Tenamene gasoline additives, send for Bulletin I-106.

For properties and shipping information on these and other Eastman products, see **Chemical Materials Catalog,** page 395, or **Chemical Week Buyers' Guide,** page 107.

Eastman



"A trunkful of gasoline inhibitor..."

"That's what he said," reports one of our sales representatives—"trunkful. And after removing fishing gear, debris from last year's vacation, plus my spare tire, that's what he got, in the form of two drums of Tenamene 3.

"The first part of the purchasing agent's late evening call was a soliloquy on the aberrations of suppliers in general. I agreed that a supplier who confused ditertiary butyl_____ (name withheld to protect the innocent) with ditertiary buty cresol (Tenamene 3*) was a bit loose in the order-writing department. At the same time I was quietly glad that we do not sell the ditertiary butyl derivative of _____. It can happen, you know.

"Anyway that's what had happened. When they were ready to stabilize a run of aviation gasoline, a sharp foreman stopped the operation before the gasoline was adulterated rather than stabilized, since as a gasoline inhibitor the _____ derivative, being insoluble, doesn't even so much as contact the problem.

"To keep gum formation from getting a head start, I went out to our local warehouse at 4:30 A.M., loaded two 100-pound drums of flake Tenamene 3 in the trunk of my car, and took off with a little prayer that there were no loose nails in the road.

"There weren't, and I arrived at the customer's refinery at 9:00 A.M."

Normally, we move Tenamene inhibitor around the country by rail freight or truck transport. If possible we'd like to continue this practice. In an emergency, however, we're prepared to give our customers maximum personal service.

Sometimes, this personal service even includes personal delivery.

*Eastman's gasoline inhibitor grade of 2,6-ditertiary butyl p-cresol.

Eastman CHEMICAL PRODUCTS, INC., KINGSPORT, TENNESSEE, Subsidiary of Eastman Kodak Company

SALES OFFICES: Eastman Chemical Products, Inc., Kingsport, Tennessee; Atlanta; Boston; Buffalo; Chicago; Cincinnati; Cleveland; Detroit; Greensboro, North Carolina; Houston; Kansas City, Missouri; New York City; Philadelphia; St. Louis.
West Coast: Wilson & Geo. Meyer & Company, San Francisco; Los Angeles; Portland; Salt Lake City; Seattle.

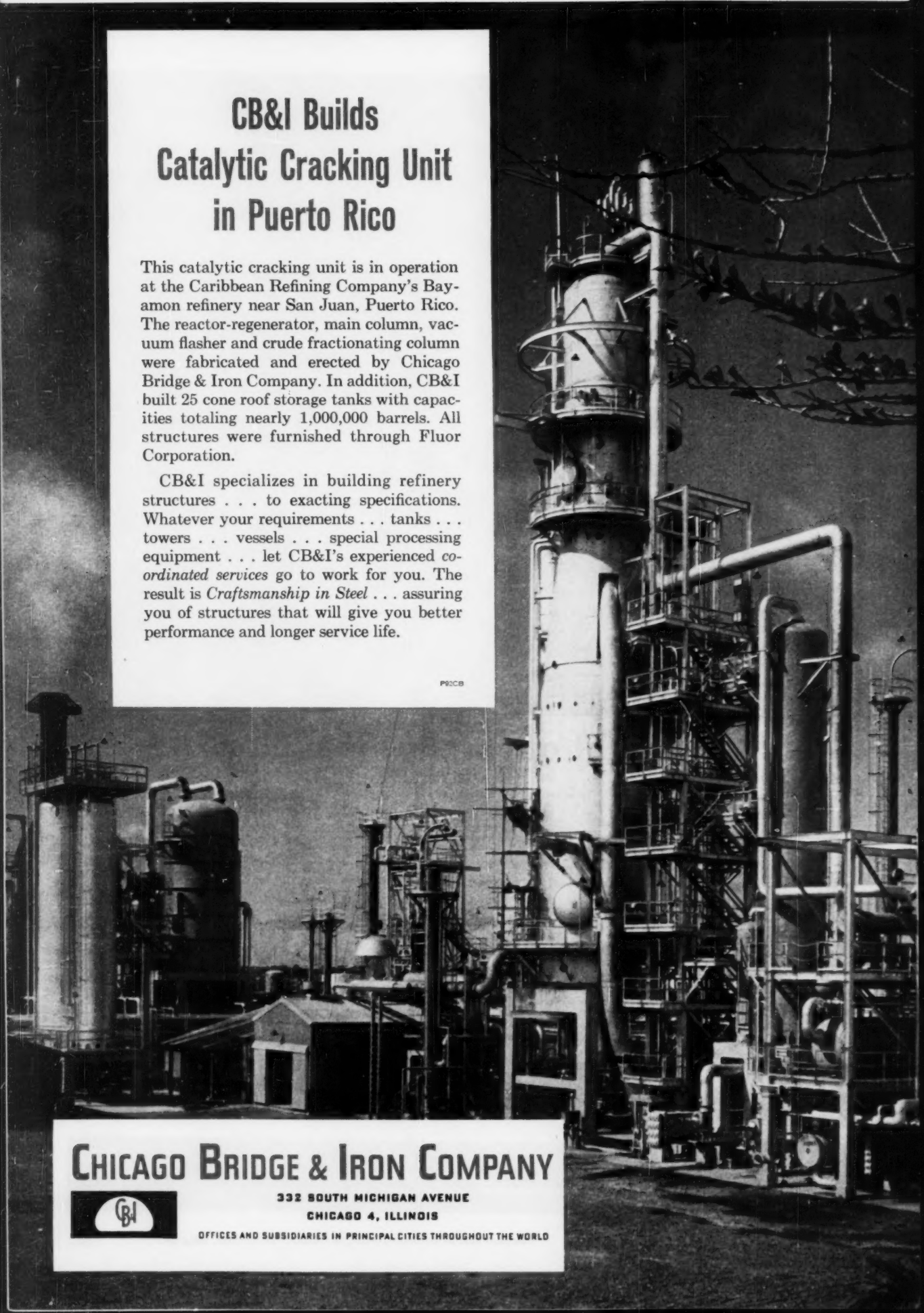
For more data on advertised products, use Readers' Service Cards, last page.

CB&I Builds Catalytic Cracking Unit in Puerto Rico

This catalytic cracking unit is in operation at the Caribbean Refining Company's Bayamon refinery near San Juan, Puerto Rico. The reactor-regenerator, main column, vacuum flasher and crude fractionating column were fabricated and erected by Chicago Bridge & Iron Company. In addition, CB&I built 25 cone roof storage tanks with capacities totaling nearly 1,000,000 barrels. All structures were furnished through Fluor Corporation.

CB&I specializes in building refinery structures . . . to exacting specifications. Whatever your requirements . . . tanks . . . towers . . . vessels . . . special processing equipment . . . let CB&I's experienced *coordinated services* go to work for you. The result is *Craftsmanship in Steel* . . . assuring you of structures that will give you better performance and longer service life.

P93CB



CHICAGO BRIDGE & IRON COMPANY

332 SOUTH MICHIGAN AVENUE
CHICAGO 4, ILLINOIS

OFFICES AND SUBSIDIARIES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

Suppliers . . .

Equipment will represent Atlas in North Carolina, South Carolina and Eastern Tennessee.

H. K. PORTER CO., INC.'s Refractories Division has appointed **R. C. Conover** general works manager. He was previously Western district works manager. He will operate from the division's Pittsburgh headquarters.

PACIFIC PIPE CO., San Francisco, has been appointed a distributor for Alloy Steel Products Co., Inc., Pacific Pipe will stock the entire line of Aloyco corrosion resistant valves for sales in Northern California.

BORG-WARNER, LTD., has appointed **John R. Mueller** general manager of chain and sprocket operations. Mueller is now vice president in charge of engineering for Morse Chain Co. and will retain this position. He was vice president and chief engineer for the Eberhart-Denver Co. at the time of the concern's acquisition by Borg-Warner in February 1956.

GROVE VALVE AND REGULATOR CO. has promoted **George E. Doty,** formerly vice

Doty

Hancock

Bird

president of sales, to vice president and general sales manager. **B. J. Hancock,** formerly Eastern regional sales manager, has been named vice president, sales. **E. C. (Early) Bird** has been appointed a district sales manager in Houston. He will now handle sales of production valves in that region. Bird was previously a division manager for Gulf Coast Machine & Supply Co.

ORR & SEMBOWER, INC., has appointed **Richard W. Lamp** manager of production. Lamp was formerly with Aeroil Products Co., and the Heil Co.

AMERICAN METER CO. has named **Henry H. Mayer** sales representative for the Mid-West Sales Division. He graduated from Princeton University.

SCIENTIFIC AND PROCESS INSTRUMENTS DIVISIONS, Beckman Instruments, Inc., has transferred its Midwestern sales and service headquarters to expand facilities at 7360 North Lincoln Ave., Lincolnwood 46, Ill. The division's regional office was formerly located at 4914 West Belmont Ave., Chicago.

DASHEW BUSINESS MACHINES, INC., has appointed **Boris Krass** branch manager, New York operations. Krass will head the Service Bureau at 342 Madison Ave. Formerly with Standard Register Co., he held the positions of New York district sales manager and district sales manager, Pacific Division, Daystrom, Inc., before joining Dashew in 1959.

ALLIS-CHALMERS MANUFACTURING CO.'s Control Department has appointed **R. C. Bown** manager of sales. Bown succeeds **G. G. Brooks,** who has been transferred to Allis-Chalmers' associate company, Consolidated Systems Corp. Bown has been with the firm since 1946.

GENERAL RUBBER CORP. has acquired the title and all rights to the SoundZorber trademark for the wire-reinforced rubber pipe formerly manufactured by T. R. Finn & Co., Inc.

CONTINENTAL-EMSCO CO.'s Fibercast Co. has promoted **Dwight G. Barnhart** sales manager. Barnhart was formerly a district tubular representative for Continen-

ONE PUMP FILLS TIN CANS OR TANKERS

Vari-Flo changes capacity instantly

Do you have pumping jobs that vary from a "dribble" to a "gusher"? Then, you should learn about the new Blackmer Vari-Flo . . . the variable-capacity pump that just might do the job several pumps are doing for you now. The Vari-Flo is much like the Blackmer vane-type rotary pumps you know about, but it has the important addition of a dial-operated "flow changer" that varies the capacity of the pump. Does it with an ordinary standard motor, too . . . no costly variable-speed drive is needed. Whether you're filling a tin can or a tanker, you can dial the proper flow rate as easily as phoning your Blackmer distributor. Which, by the way, is a very good idea if you see a chance for an application. Or, write for Bulletin 600.

"liquid materials handling"® equipment

BLACKMER / *vari-flo pumps*

BLACKMER PUMP COMPANY, GRAND RAPIDS 9, MICHIGAN

Find your Blackmer Man under "Pumps" in the Yellow Pages

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

tal-Emsco. He will be located at Fiber-cast's plant, Sand Springs, Okla. He joined Continental Emsco in 1955 as a trainee.

BECKMAN INSTRUMENTS, INC.'s, Scientific and Process Instruments Division has named **Harry H. Bauer** Midwestern regional sales manager. Bauer, who will direct the division's field sales force in the Midwestern region, has been a product line manager in Beckman's Fullerton, Calif., office.

MINNEAPOLIS-HONEYWELL REGULATOR CO.'s Datamatic Division has opened 10 new sales offices located in Atlanta, Cincinnati, Cleveland, Houston, Minneapolis, Philadelphia, Pittsburgh, San Francisco, Portland (Ore.) and Albany.

SPARKLER MANUFACTURING CO., producers of industrial, commercial and municipal filtration equipment, has opened its newly constructed sales headquarters and plant in Conroe, Texas. Sparkler moved its operation from two plants in Mundelein and North Chicago, Ill., last March 31.

TRW COMPUTERS CO. has been announced as the new name for The Thompson-Ramo-Wooldridge Products Co. The company will continue to function as a computer division of Thompson-Ramo-Wooldridge, Inc. Headquarters will remain in Beverly Hills, Calif.

J. I. CASE CO. has appointed **Edward F. Hyland** general supervisor of public relations. Hyland has been with Case for 17 years as manpower director. Prior to joining Case, he was employed by Highway Trailer Co., American Cigar Co. and U.S. Government.

CUMMINS ENGINE CO., INC., has promoted **C. R. Boll** to executive vice president, marketing. **R. W. Franck** has been named

Boll

Franck

vice president, sales. Boll joined the firm after graduating from Purdue University. Franck came to Cummins in 1948 as a market research analyst.

WOLVERINE TUBE DIVISION has named **C. D. McDowell** heat transfer specialist in Tulsa. Formerly with Refinery Engineering Co. as sales representative, McDowell will handle sales of finned-tube and condenser-tube products in copper, copper alloy and aluminum.

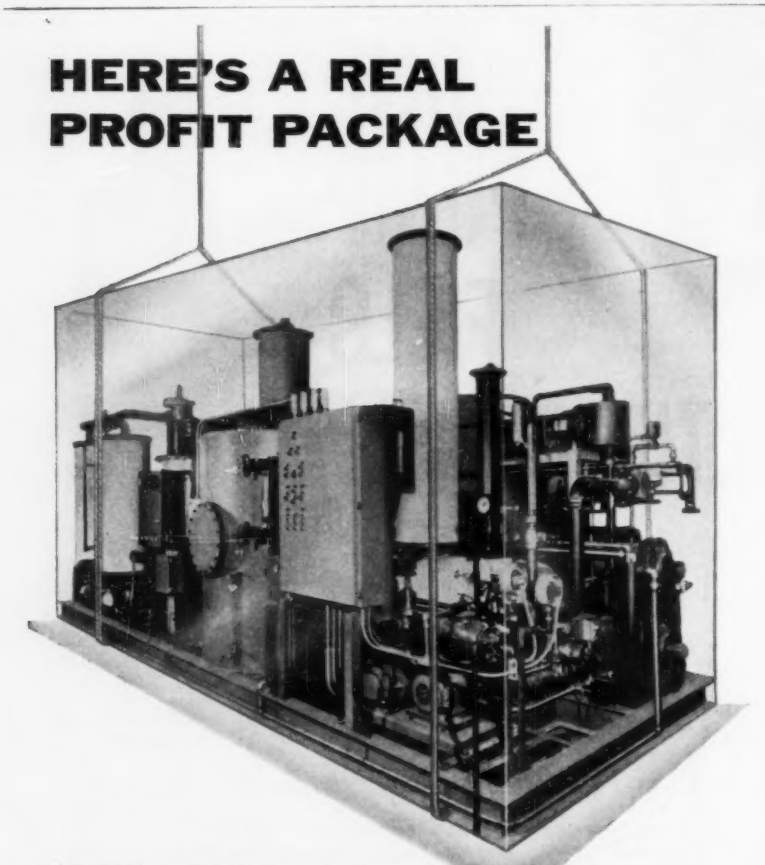
KAISER STEEL CORP. has appointed **Donald H. Weatherbe** district credit manager, Southern sales district. He will headquarter in Los Angeles. Weatherbe joined the Credit Department, Kaiser Steel, in 1953 as credit analyst, later being named district credit manager for the company's Northwest sales district.

AIR REDUCTION SALES CO. has named **C. J. Langley** assistant district manager in Philadelphia. Langley will assist **N. F. Moody,** district manager, in the sale and distribution of all Airco products marketed through the Philadelphia district. Langley joined Airco in 1946 in the Technical Sales Department.

TRIANGLE VALVE CO., LTD., Wigan, England, has promoted **A. L. Kennedy** to works director. He has been works manager for the past 12 years.

CONSOLIDATED ELECTRODYNAMICS CORP. has appointed **Robert F. Cummings** manager of administrative services, and **Frank B. Wiens** manager of engineering services, at the corporation's research center. Cummings joined the research center in 1959 as staff assistant. Wiens joined Consolidated in 1945.

M. H. DETRICK CO.'s Insulation Division has named **T. J. Pohl** sales manager. Pohl



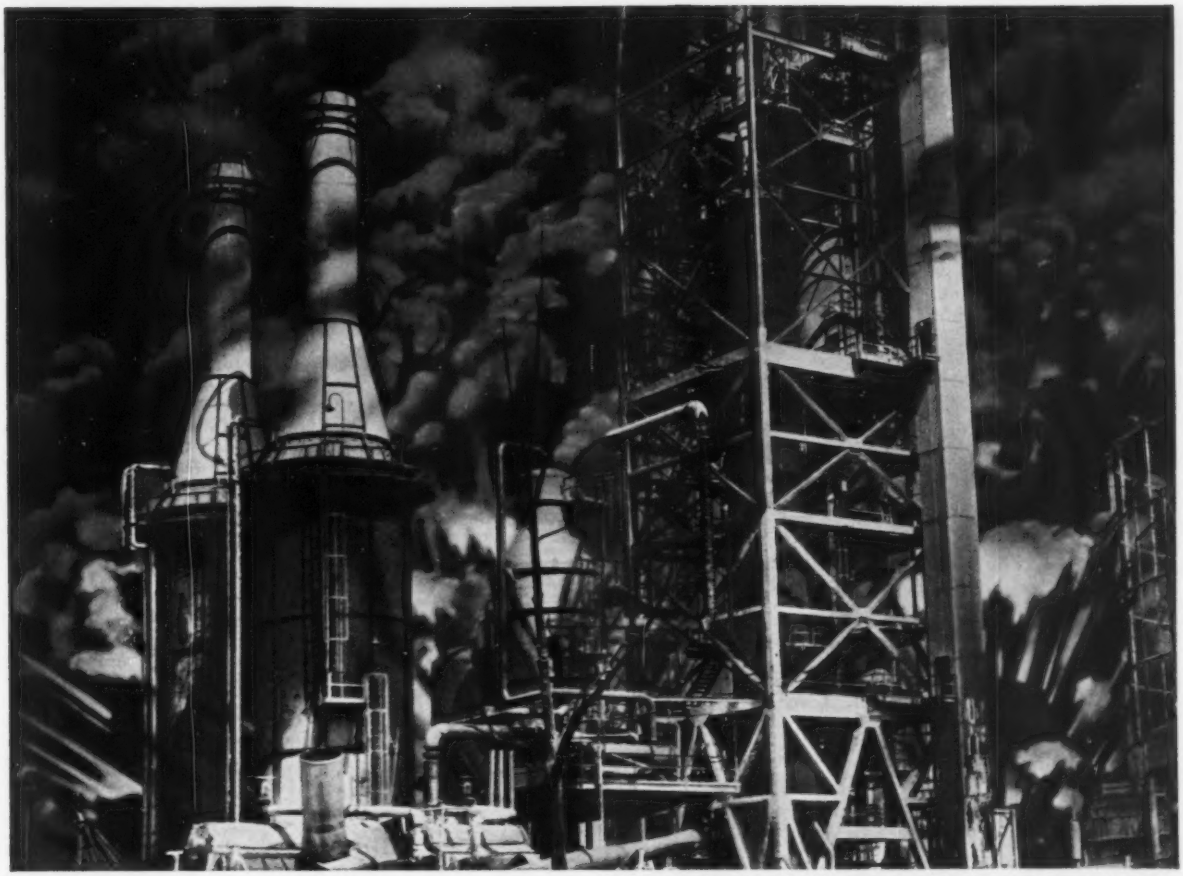
for minimum volume gas users . . . a single base, completely packaged gas generator that will produce all the gas you want, when you want it, at lowest possible costs. Even minimum gas users have found they can amortize the cost of an efficient Gas Atmospheres system over a few short months.

Gas Atmospheres builds factory assembled and tested packaged units for the production of reducing, nitrogen, carbon dioxide, hydrogen, inert and annealing atmospheres for use in the metal, food, petroleum and chemical industries—from 50 cfh to 50,000 cfh. If you use gas why not make certain you have the most efficient operation possible. Call in your Gas Atmospheres engineer today or write direct to *Gas Atmospheres, Inc., 3855 West 150th Street, Cleveland 11, Ohio.*

THE NATION'S LARGEST MANUFACTURER OF PACKAGED GAS GENERATOR SYSTEMS

gas Atmospheres, inc
3855 West 150th Street • Cleveland 11, Ohio

For more data on advertised products, use Readers' Service Cards, last page.



Protected by L. W. Blazecrete—this structure was virtually undamaged by 2 to 6 hours of *direct* flame exposure

Protected by Johns-Manville L. W. Blazecrete . . .

vital equipment is undamaged by 3 days of explosive fire!

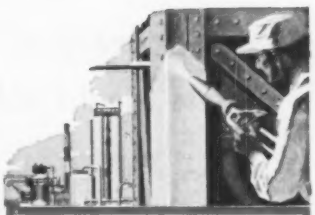
AFTER MORE than seventy hours of fire and explosion had spread from storage tanks to one of the world's most modern thermofor catalytic plants, damage was estimated at nearly 8 million dollars.

Yet the flames didn't destroy the entire plant. Vital equipment, key structural members and control areas . . . made fire safe by J-M's L. W. Blazecrete®. . . were virtually undamaged. This simple, low-cost protection paid for itself countless times over by providing an effective shield against 2 to 6 hours of direct flame exposure.

In your plant, too, Johns-Manville L. W. Blazecrete can save you money . . . for fire control and for lining high-temperature equipment.

A hydraulic-setting refractory—Johns-Manville L. W. Blazecrete is quickly, easily applied to equipment and structural members . . . and to linings of high-temperature equipment. For troweling, just mix L. W. Blazecrete with water as you'd mix ordinary concrete—then slap trowel in place. When gunned, L. W. Blazecrete adheres readily with a minimum of rebound loss. Whether used for fire protection or for linings—L. W. *Blazecrete lasts!*

Find out more about this newest of fire protection ideas, and about the application of L. W. Blazecrete throughout the petroleum industry. Write to Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.



Gunned in place or slap troweled L. W. Blazecrete is the ideal material for refractory linings. It gives you an unusually strong, dense and homogeneous lining . . . ready for use within 24 hours.

JOHNS-MANVILLE

JOHNS-MANVILLE JM PRODUCTS

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

joined the Detrick organization in September 1959, and will be headquartered in the firm's main office, Chicago.

IMPERIAL BRASS MANUFACTURING CO. has appointed **Martin J. Butler, Jr.,** manager of marketing services. Butler comes to Imperial from The Diversey Corp., where he was advertising and sales promotion manager for seven years. He succeeds **E. F. Todd,** who has retired.

UNITED STATES RUBBER CO.'s U.S. Tires Division has appointed **Fred R. Bates** manager of oil marketer sales. **W. E. Crouch,** formerly manager of batteries and accessories, has been named central manager of oil marketer sales.

PHILIPS METALONICS, producer of dispenser cathodes and machined tungsten parts, has moved its divisional headquarters and production facilities to 888 South Columbus Ave., Mount Vernon, N.Y. Formerly, operations were carried out at Irvington-on-Hudson, N.Y.

LEHIGH FAN AND BLOWER DIVISION, Fuller Co., has appointed **Harley Yake** sales and service representative. Yake's territory covers Eastern Washington, Northern Idaho, and Western Montana.

Specialized EFCO Experience

Solves Specific HEAT TRANSFER PROBLEMS . . .

Years of experience in engineering and fabricating of heat exchangers for the wide range of temperatures/pressures encountered in refining-petrochemical-natural gasoline plant processes enables EFCO to offer service-proved engineering design and guaranteed job rating. Gulf Oil Corporation is one of many process equipment users who are benefiting from EFCO's specialized experience and engineering efficiency.

This Gulf Oil Corporation installation of Efco units, in Gulf's Port Arthur Refinery, is typical of the many high-pressure, high-temperature exchangers designed and fabricated by EFCO.

EFCO'S FOUR POINT PROGRAM PROVIDES:

- service-proved engineering design
- guaranteed job-ratings
- complete fabricating facilities
- technical service before, during and after installation

ASK OUR GULF COAST CUSTOMERS—THEY KNOW US WELL

Write for General Catalog

ENGINEERS AND FABRICATORS, INC.

P. O. BOX 7395 • HOUSTON 8, TEXAS

116

IVAN SORVALL, INC., Norwalk, Conn., has named **Virgil A. Lindgren** area sales representative in the mid-Atlantic and Southeastern states. Working out of Bethesda, Md., Lindgren will sell and service the company's laboratory instruments. Lindgren graduated from Gustavus Adolphus College, St. Peter, Minn., and was with Hood Rubber Co. before joining Ivan Sorvall.

Lindgren

ARCO-WYNN VALVE DIVISION, Automotive Rubber Co., has named **Philip T. Rogers** vice president and general manager. Rogers was formerly a regional manager for Hills-McCanna Co., Chicago.

KILBY STEEL CO., Anniston, Ala., has opened a Houston sales office under the direction of **George M. Tope,** sales manager. Kilby Steel manufactures seamless, extruded pressure tubing, mechanical tubing and boiler tubing in carbon and alloy grades, for use in the refining, petrochemical and manufacturing industries.

COMPUDYNE CORP., Hatboro, Pa., has appointed **Harry A. Lucas, Jr.,** former sales manager, Minneapolis-Honeywell Regulator Co.'s Systems Division, corporate sales consultant.

SCIENTIFIC AND PROCESS INSTRUMENTS DIVISION, Beckman Instruments, Inc., has appointed **James E. Tebay** training manager. He will be responsible for training dealers and customers in the use of instruments marketed by the division, as well as sales and service training of dealers and Beckman personnel.

CONSOLIDATED ELECTRODYNAMICS CORP. has elected **Jack H. Zillman** vice president, data processing divisions. For the past three years, Zillman has been vice president and general manager, Pacific Division, Daystrom, Inc.

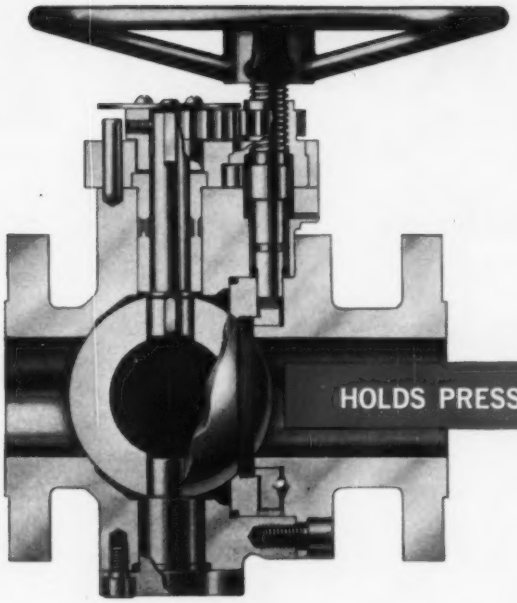
ROCKWELL MANUFACTURING CO.'s Petroleum & Industrial Meter Division has named **J. W. Northcutt** assistant vice president and manager. He was formerly an assistant vice president in Rockwell's Municipal & Utility Division. Northcutt joined Rockwell in 1937 as a sales engineer, was promoted to Atlanta, Ga. district manager in 1949 and Southern regional manager in 1952. He became an assistant vice president in 1956.

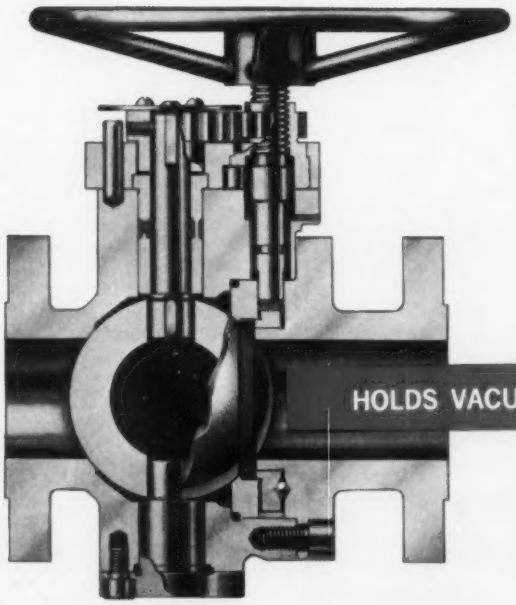
Northcutt

DATEX CORP. has promoted **James W. Krebs** to manager, Datex Midwest regional office, Skokie, Ill. Krebs joined

For more data on advertised products, use Readers' Service Cards, last page.

Exclusive Controlled Compressible Port Seal provides fast, positive shutoff in any service...





HYDRIL BALL Type "K" PLUG VALVES

Controlled sealing . . . a new concept in valve design . . . is the secret of Hydril's tight, bubble-proof shutoff. Hydril Ball-Plug Valves always seal positively against pressure from either direction—or against vacuum—because the fully confined packing ring is mechanically compressed between plug and seat when the valve is closed. This tightly compressed gasket type seal easily bridges clearances between parts as well as surface imperfections. Result: seal efficiency is unimpaired by prolonged hard usage, by rust or sediment.

Design of Hydril Type "K" Ball Plug Valves assures minimum maintenance costs. Non-lubricated, they employ no sealing lubricants. There's no sliding friction between plug and body to produce wear and abrasion.

The spherical plug is mounted on accurately positioned bearings, maintaining a minimal controlled clearance between plug and body. This contributes to easy, free-turning operation as well as to long service life.

●

Hydril valves are available in a wide range of sizes and ratings. Worm-gear and motor-operated models can be supplied. Get the full story on Hydril Valves from your nearby representative . . . or write Hydril Company for free Catalog No. V-60.

HYDRIL COMPANY

714 West Olympic Boulevard, Los Angeles 15, Calif.

Factories at: Los Angeles; Houston, Texas; Rochester, Pa.
Sales Offices: California: Bakersfield, Los Angeles, Ventura • **Louisiana:** Harvey, New Iberia, Shreveport **Oklahoma:** Oklahoma City, Tulsa • **Texas:** Corpus Christi, Dallas, Houston, Midland, Odessa • **Wyoming:** Casper **New York:** New York • **Canada:** Calgary, Edmonton

For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

Datex as a sales engineer in the Midwest office last January. He was formerly with Gilmore Industries.

F & M SCIENTIFIC CORP., analytical instrumentation manufacturers, has opened a Midwestern sales office in Chicago. **Richard Craig** will be director of the new office.

COMPUDYNE CORP. has named **George E. Gilliam** regional sales manager. Gilliam was with Minneapolis-Honeywell Regulator Co. for 17 years before joining CompuDyne.

BLACK, SIVALLS & BRYSON, INC.'s Controls Division has transferred **Jim Lawrence** to Houston as sales engineer and **Jon Young** to Denver. **Les Stillwell** has been assigned to Los Angeles as sales engineer. **Jim Martin** has been named sales engineer at Borger, Texas.

AIR REDUCTION SALES CO.'s Special Products Department has promoted **Roger W. Tuthill** manager of engineering. He has been with Airco since 1958. Before his present appointment, he was assistant manager, Equipment Engineering and Development Department.

KEROTEST MANUFACTURING CO. has promoted **Kirk P. Harger** Eastern sales manager, Steel Products Division.

LINK-BELT CO. has appointed **William R. Palmer** manager, Dallas, Texas, district and factory branch store. He was

Palmer

Boyce

previously district manager in Shreveport, La. He joined Link-Belt in 1948. J. William Boyce, former district sales engineer, Chicago district office, succeeds Palmer as district manager at Shreveport.

WESTERN SUPPLY CO. has appointed **W. F. Roberts** sales engineer, Heat Exchanger Division. Roberts will cover the mid-continent area for Western. Before joining Western, he was Oklahoma district representative for Yuba Consolidated Industries. He graduated from Oklahoma State University in 1945. He holds B.S. and M.S. degrees from the university. Roberts has been in the chemical and heat transfer field for 13 years.

Roberts

TRUSCON LABORATORIES, Detroit, has elected **Alvin S. Baer** vice president. Baer was formerly general manager of Sonneborn Chemical & Refining Corp., Building Products Division, and prior to that was general manager of A. C. Horn Corp., a division of Sun Chemical Corp.

TEMPERATURE ENGINEERING CORP. has elected **Norman Burstein** vice president in charge of marketing. Burstein has been with the company since it was founded, and was previously sales manager. **Charles Gardner** has been named plant manager and **Richard Ditzler** has become director of research and development.

BAIRD-ATOMIC, INC., has opened a sales and service office in Cleveland, Ohio. **Alexander V. Evans,** sales engineer, will be in charge. Evans was formerly with the firm's Pittsburgh office.

HENDRICK MANUFACTURING CO. has appointed **Benjamin G. Dann, Jr.,** director of production. Dann has been with Hen-

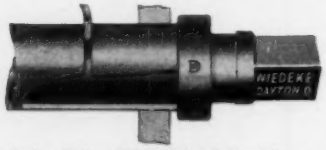
WIEDEKE

THE QUALITY NAME IN TUBE EXPANDERS . . . SINCE 1892

Tube Expanders and Cutters for Condensers

No. 255—for average tube sheets

No. 270—for thick or multiple tube sheets



Series 400—IDEAL Tube Cutter (shown in use) for non-Ferrous Tubes. Available in sizes for ⅝" and larger Tubes.

#37

IDEAL

Confidence is your assurance that IDEAL products will get your job done—and done *right*. The Gustav Wiedeke Company has specialized in Tube Expanders, Tube Cutters, and Operating Accessories since 1892. Write for new General Catalog 81.

The Gustav WIEDEKE Company

DAYTON 1, OHIO

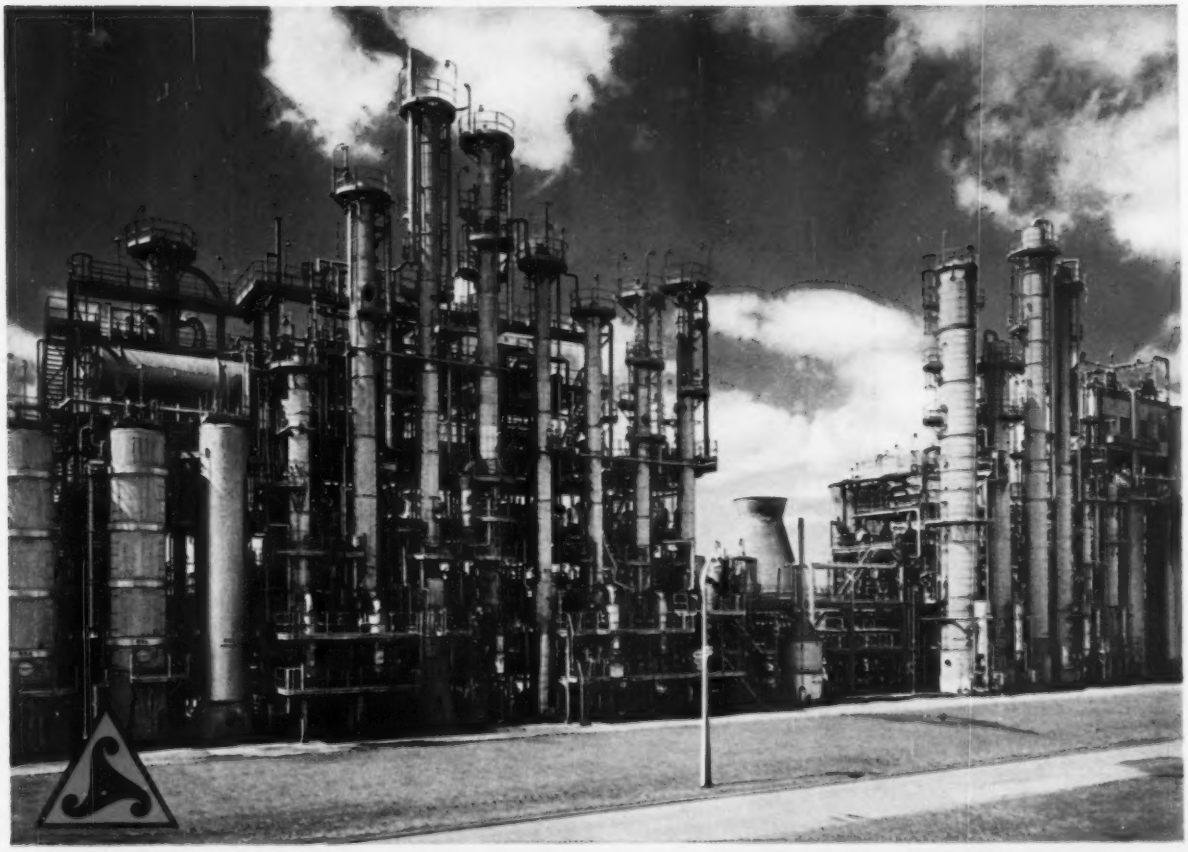
BRITISH PREMIERE

STONE & WEBSTER ENGINEERS BRITAIN'S FIRST CUMENE-PHENOL PLANT

British Hydrocarbon Chemicals Limited's Cumene-Phenol Plant, the first in Britain, was recently completed by Stone & Webster Engineering Corporation, a pioneer in the design and construction of phenol plants in both the United States and Japan.

The new installation is the tenth project designed and constructed by Stone & Webster for BHC at Grangemouth since 1950. The Cumene Unit employs the process of Scientific Design Company Inc. while the Phenol Unit utilizes that developed by The Distillers Company Limited.

Stone & Webster's unequalled experience and engineering skill in the process field can be of profit to you on your next project. Write or call our nearest office.



STONE & WEBSTER ENGINEERING CORPORATION

Affiliated with Stone & Webster Engineering Limited (London)

New York Boston Chicago Pittsburgh Houston San Francisco Los Angeles Seattle Toronto

M·A·N

The following are some of the products we design and manufacture:

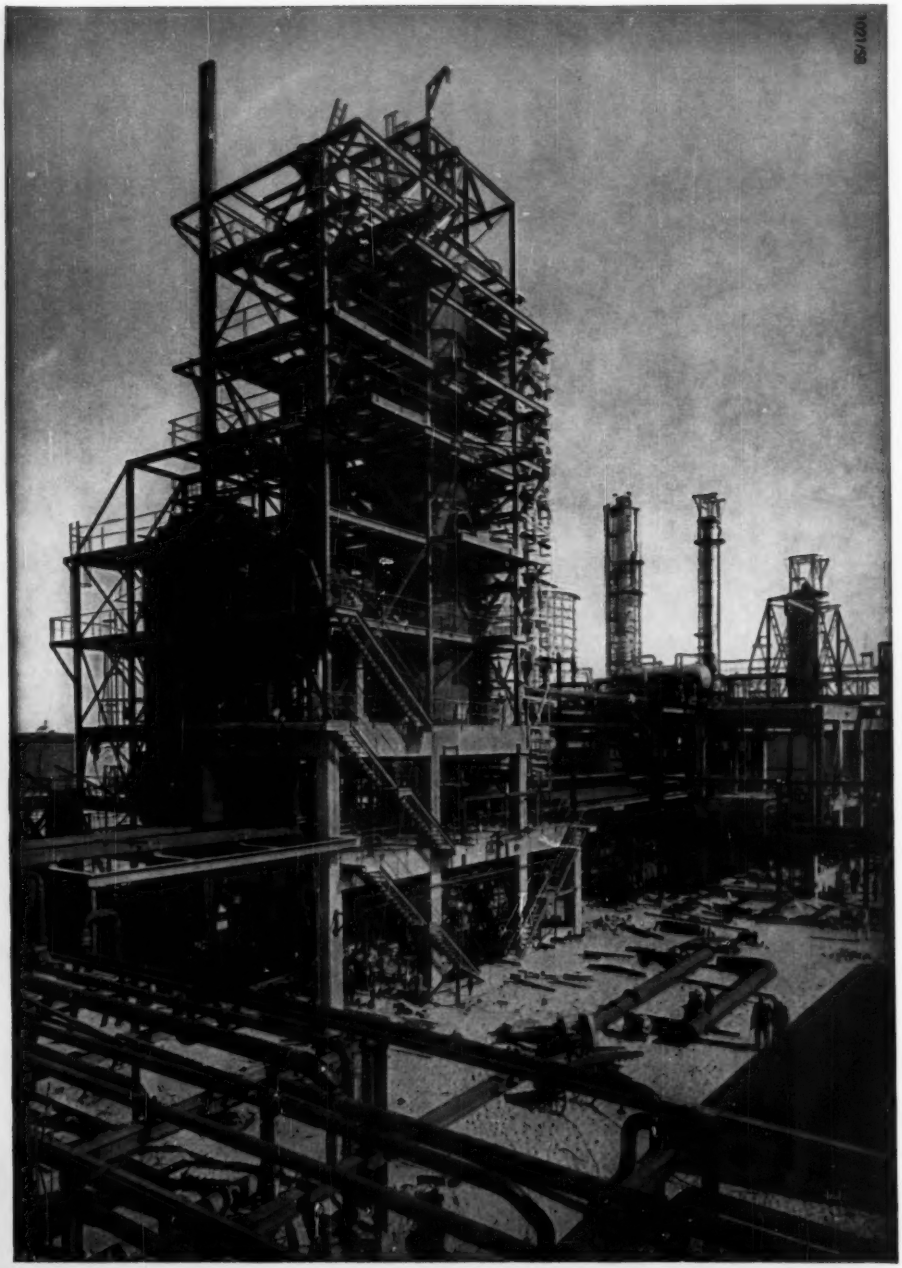
STEAM BOILERS

STEAM POWER STATIONS

TURBINES

DIESEL ENGINES

GAS ENGINES



Responsible for process and engineering were:
N. V. de Bataafsche Petroleum Mij., The Hague
and Lummus Nederland N. V., The Hague.
Responsible for purchasing was:
Edeleanu GmbH, Frankfurt.

We recently supplied and installed all apparatuses and structural steelwork required for the

CAT CRACKER AND GAS RECOVERY PLANT
DEUTSCHE SHELL AG
HOHE SCHAAR REFINERY, HAMBURG

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORKS
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Suppliers . . .

drick for the past 18 years. He became plant engineer in 1951 and was elected to the board of directors in 1957. He received his B.S. degree in mechanical engineering from Massachusetts Institute of Technology in 1948.

RUSSELL & STOLL CO., electrical equipment manufacturers, has appointed **W. G. Caputo** sales representative with headquarters in Chicago. Caputo has been with Westinghouse Electric Corp. in various sales capacities.

BORG-WARNER CORP. has elected **Frank W. Rickard** group vice president. Rickard joined Borg-Warner in 1953 as director of manufacturing services.

DATAMATIC DIVISION of Minneapolis-Honeywell Regulator Co. has appointed **Thomas H. Wilder III,** manager, San Francisco branch sales office. Wilder, formerly division director of Broadview Research Corp., joined Datamatic in July 1960.

JONES & LAUGHLIN SUPPLY DIVISION has named **R. J. Bevington** store manager at Freer, Texas. He was previously salesman at McAllen, Texas. **R. S. Allison** has

Bevington

Allison

been promoted to store manager at Lake Charles, La., from salesman at Beaumont, Texas. Bevington joined the division in 1949. Allison started with the firm in 1935.

AMERICAN POTASH & CHEMICAL CORP. has named **William W. Young** Southern area regional sales manager. Young, who will open the company's first regional headquarters at Atlanta, Ga., will have sales and administrative responsibility for the Atlanta and Shreveport district offices. **Niven D. Morgan, Jr.,** formerly sales representative at Shreveport, replaces Young as district manager at that office.

MONSANTO CHEMICAL CO. has appointed **William W. Low** sales representative in the company's Inorganic Chemicals Division, Houston. **O. Lee Ryser** has been chosen assistant district sales manager for the firm's Inorganic Chemicals Division, Atlanta, Ga.

ARMSTRONG CORK CO. has named **John D. Mink** assistant manager of the Dunkirk, Ind., glass plant. **Albert J. Diener** is the new general plant superintendent and **Michael J. Urmon** is production superintendent.

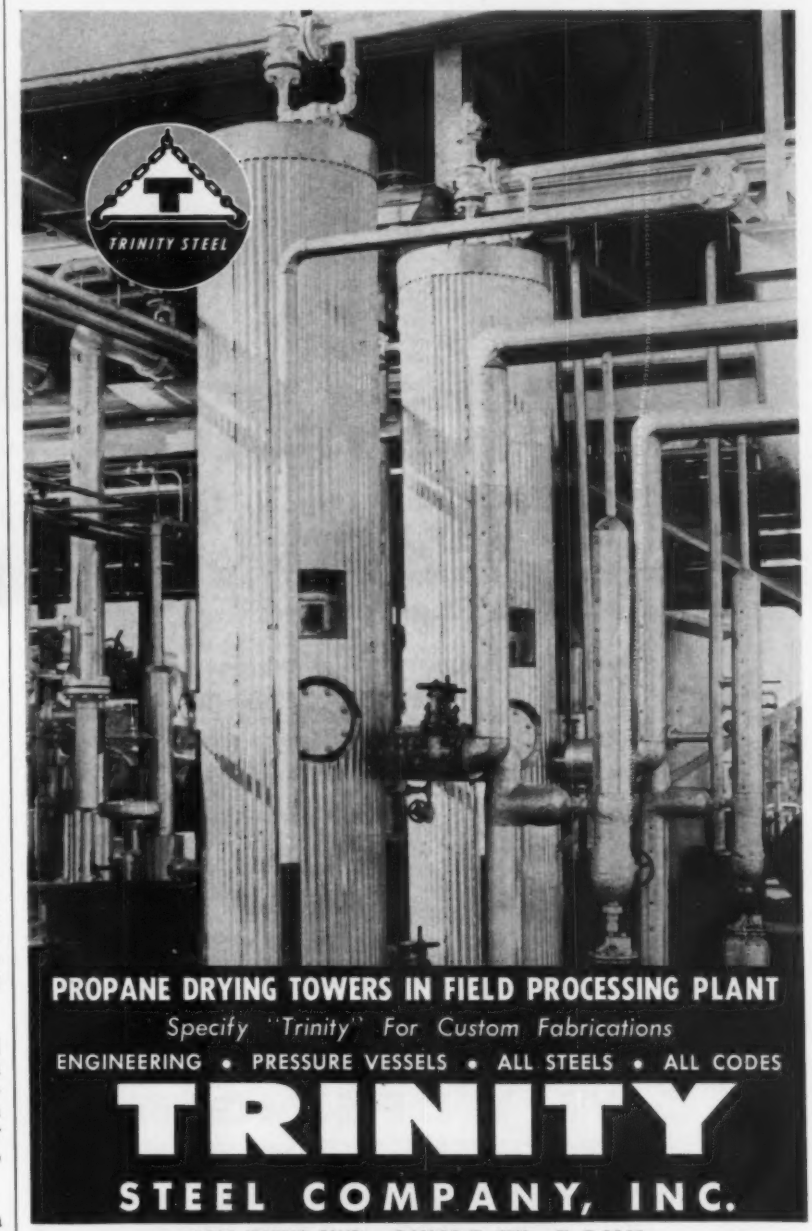
GROVE VALVE AND REGULATOR CO. has licensed two additional European firms to produce its G-4 gate valve. The licensees are Nuovo Pignone, Firenze, Italy, and Robert Cort & Son, Ltd., Reading, England.

CLARK BROS. CO. has announced the sale by Clark Compressor Co. Ltd., Calgary, Alta., of three gas turbine centrifugal compressor sets to Trans-Canada Pipe Lines Ltd., as part of Trans-Canada's expansion program to export natural gas to the United States.

GENERAL REFRACTORIES CO. has named **Frank J. Keenan** assistant controller. Keenan is a certified public accountant. He was with Lybrand, Ross Bros. and Montgomery for 16 years prior to joining General Refractories in 1957.

DIAMOND ALKALI CO. has appointed **R. G. Richards** director of development. Richards joined Diamond in 1952 as a technical service representative.

CONSOLIDATED SYSTEMS CORP. has appointed **Capt. Frank W. Taylor,** a retired U.S. Naval officer, assistant to the engineering vice president. Taylor graduated from the U.S. Naval Academy and has an M.S. degree in naval construction



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For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

and engineering from Massachusetts Institute of Technology.

BURGESS-MANNING CO. has elected **Tom P. Walker**, former chairman of the board of Transcontinental Gas Pipe Line Corp., to the board of directors.

WOLVERINE TUBE DIVISION, Calumet & Hecla, Inc., has appointed **L. A. Brewer** manager of sales administration. Brewer joined the company as sales representative in the New York district in 1959. He was manager of strubing sales before his present appointment.

YOUNG RADIATOR CO. has appointed **Forest D. Richardson** treasurer in charge of finance and business administration. Prior to his appointment at Young Radiator, Richardson was general manager of administrative services, including accounting, purchasing and personnel at Good-All Electric Manufacturing Co., a division of Thompson-Ramo-Wooldridge, Inc., in Ogallala, Neb. He graduated from the University of Chicago.

Richardson

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Continuing business through the years has established the C. W. Nofsinger Company's recognition in petroleum, chemical and petro-chemical engineering. Repeat orders from satisfied clients speak strongly in our behalf.
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Los Angeles 14, Calif.
Representatives
GULF COAST
Russell G. Dressler
204 Carolwood Drive
San Antonio, Texas

OAKITE PRODUCTS, INC., has elected **Peter J. Kornett** to the board of directors. Kornett, a graduate of the College of the City of New York, joined Oakite in 1941 as a control chemist. He is now the company's general manager of manufacturing.

MORSE CHAIN CO. has named **Robert J. Koch** Southwest regional sales manager. Koch's headquarters will be in Houston. His territory will include the states of Texas, Louisiana, Mississippi, Oklahoma and Southern New Mexico. Koch has been with Morse Chain for 3 years.

PERMANENT FILTER CORP. has named **Herbert H. Howard** director of research and development. **Paris H. Stafford** has been appointed chief engineer. Howard has been with Permanent Filter since 1952. Stafford has been with North American Aviation, Autonetics Division, for the past eight years.

Howard

Stafford

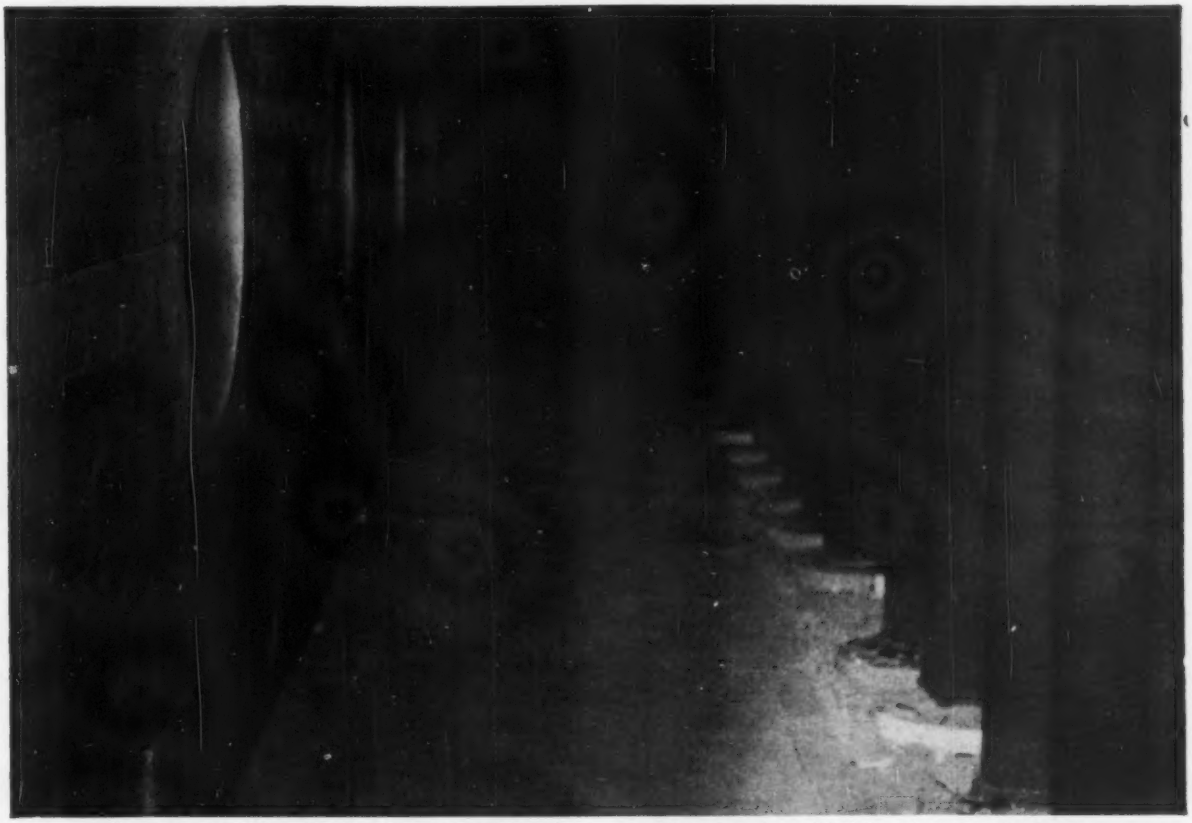
GEIGY INDUSTRIAL CHEMICALS DIVISION has named **Milton Rosenberg** product manager, Customer Service Department, in charge of surfactants. Rosenberg will direct a laboratory group in applications research and development on acylated amino acids and other surfactants.

TRINTITY STEEL CO., INC., has promoted **Dillard Cantrell,** formerly chief engineer, to assistant to the president. Before joining Trinity Steel, Cantrell served on the engineering staff of Ebasco. He will directly serve **W. Ray Wallace,** president in broad administrative duties, as well as heading LPG sales. He graduated from Southern Methodist University, Dallas, as a mechanical engineer. He has been with Trinity five years.

Cantrell

HOOKER CHEMICAL CORP. has named **A. Richard Perry** controller. He was assistant controller since January 1958.

BENDIX AVIATION CORP. has dropped the word "aviation" from its title and will henceforth operate under the official name, "The Bendix Corp." Reason for



Arrangement of burners (left) assures even heating of tubes (right) in Selas gas reformer. This, plus the use of iron-chromium-nickel alloy, is expected to boost tube life to ten years . . . or more . . . in California plant.

Cast nickel stainless steel proves key to long life in gas reformer parts

What causes short tube life in gas reforming furnaces?

"Flame impingement," says one operator. "Local hot spots during decoking" says another. "Improper selection of metals" says a third.

Although there are no easy answers to the complex problems posed by heat, corrosion and stress, advances in metallurgy and design are making possible greater economy in furnace operation.

Service life is sharply increased

Gas reformer tube life is being upped, today, to the point where some operators anticipate ten years or more service. That is the life California Ammonia Company expects, for example, after the first year of operating their Lathrop, California, anhydrous ammonia plant.

One reason for this, they say, is the design of their Selas furnace. It provides for individual control of recessed, radiant-heat burners. Thus Calamco can "organize" heat within the furnace for fast initial heating of feed and for uniform controlled heating of catalyst tubes, without flame impingement.

Calamco and Selas agreed on the use of iron-chromium-nickel cast alloy A.C.I. Type HK for the tubes. This 20% Nickel, 25% chromium alloy provides excellent resistance to hot gases, including sulfur bearing, under both oxidizing and reducing conditions and is one of the stronger heat-resisting materials.

If the life of furnace components in your plant is not what you desire, look into the properties of nickel-containing casting alloys. Our new booklet, "Heat- and Corrosion-Resistant Castings . . . Their Engineering Properties and Applications" makes this easy. We'll be glad to forward a copy at a word from you.

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street INCO New York 5, N. Y.

Spring suspension frees tubes to expand. Nickel alloy provides strength at high temperatures for reformer tubes (shown at bottom of photograph).

INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

For more data on advertised products, use Readers' Service Cards, last page.

CONTACTOR NUMBER 4

GLYCOL PROCESS AND DESIGN OPERATING INFORMATION

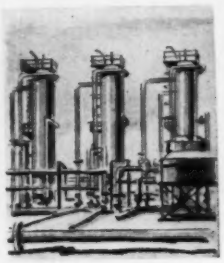
Proper use of glycols in well designed, correctly operated equipment is essential for efficient gas treating Some of these important design and operating considerations will be discussed in this series.

Dehydration with Glycols

Desiccant systems based on diethylene and triethylene glycol offer a number of economic advantages over solid dehydration units. For example, initial capital investment is less, desiccant make-up costs are lower, and operating expenditures are reduced by ⅓ to ½.

Since each operation should be considered as a special case, the following information about DEG and TEG is presented to help you determine the type of glycol best suited to your particular requirements.

Diethylene Glycol



Advantages:

1. It is stable in the presence of sulfur, oxygen and carbon at normal operating temperatures.
2. It is highly hygroscopic.
3. Carry-over losses are small.
4. It does not solidify in a concentrated solution.
5. It is non-corrosive.

Disadvantages:

1. Carry-over is greater than with TEG.
2. It cannot easily be regenerated to greater than 95% solution.
3. Dew point depression of 30-60° F. is less than with TEG. (Dew point depression is usually about 50° F.)

When oxygen and hydrogen sulfide are absent, reboiler temperatures may be raised to 330-350° F. to obtain higher concentrations of glycol and consequently greater dew point depression. Care should be exercised when using temperatures in excess of 325° F.

Triethylene Glycol

In *addition* to the advantages offered by DEG, triethylene glycol offers the following:

1. Higher dew point depressions of from 80 to 140° F. can be obtained if the TEG is dried sufficiently during regeneration.
2. TEG is easily regenerated to a 98-99.5% or higher solution in an atmosphere stripper because of its high boiling point.
3. It has a theoretical decomposition temperature of 404° F., while the temperature of DEG is 328° F.
4. Vapor pressure is 20% lower than DEG at 80° F. Thus, vaporization losses are lower.
5. Simpler regeneration equipment is required.
6. Dehydration is less expensive than with DEG — both in operating and capital costs.

Disadvantages:

1. The presence of light liquid hydrocarbons produce a tendency for foaming. The use of anti-foam agents is indicated to help control this condition.
2. Normally, it is not possible to obtain dew points as low as with solid desiccants.

In some instances, it may be possible for an operator to convert DEG units for use with triethylene glycol.

Operating Considerations

Gas temperature is a determining factor in the operation of liquid desiccant plants. Dew point depression as high as 96° F. has been obtained with TEG and 65° F. with DEG. If gas temperature is too high to give the desired water content in the dried gas, cooling should be considered. Since the initial cost of a TEG dehydration plant is generally less than half that of a dry desiccant plant, expenditure for cooling the gas is justified.

Methods of cooling fall into three basic categories: (1) Cooling by expanding the gas just ahead of the dehydrating unit . . . if pressure drop is available; (2) Use of various types of water coolers; and (3) Refrigeration. This may be accomplished by compressing the gas, removing the heat of compression and expanding, or by use of an external refrigeration unit.

In cases where an operator has an existing glycol dehydration plant which cannot meet newer, more rigid specifications for water content, consideration should be given to cooling the inlet gas or treating the gas from the glycol dehydrator in a small solid desiccant unit. These steps should be sufficient to place an existing glycol unit back into useful operation.

In cases where cooling does not provide sufficient water removal, a small solid desiccant unit may be used. This is practical, since much smaller units are needed than would be required for complete removal of water contained in the gas.

Cost of operating a glycol dehydration plant is approximately 20-60 cents per million standard cubic feet of gas. The economy of this system is apparent when one considers the cost of operating a dry desiccant plant, which is in the range of $0.60-$1.20 per million standard cubic feet of gas.

FOR MORE INFORMATION, look for future issues of Allied Chemical Contactor featuring articles on ethanolamines and glycols in gas treating operations.

We will gladly send technical data, delivery and price information on Allied Chemical Ethanolamines and Ethylene Glycols.

For specifications and local offices, see our insert in Chemical Materials Catalog, pages 475-482 and in Chemical Week Buyers Guide, pages 37-44.

BASIC TO AMERICA'S PROGRESS

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NITROGEN DIVISION

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2819

Suppliers . . .

the change comes from the fact that the firm sells and manufactures other products in addition to aviation products.

A. O. SMITH CORP.'s Atomic and Process Equipment Division has named **Harry K. Brill** general sales manager. Brill joined A. O. Smith in 1947 as a sales engineer

Brill

Lawson

in Houston. **Andrew L. Lawson,** who joined the company in 1948, has been made manager of atomic equipment.

WALWORTH CO. has appointed **Gustav A. Hoffman** vice president, sales. Hoffman will be returning to the company he served for 27 years. He left in 1959, while holding the position of assistant vice president in charge of Metropolitan sales. Hoffman joined Walworth in 1932. He entered company sales four years later, and was appointed sales manager of Philadelphia area in 1940. He returned to Walworth in 1946 after four years of service in the U.S. Navy. He subsequently managed the Kansas City and Detroit sales areas prior to being appointed manager of the Metropolitan Division in 1955.

Hoffman

BENDIX COMPUTER DIVISION, The Bendix Corp., has named **Delmer C. Davis** to the sales enginering staff. Davis will cover sales for Arkansas, Oklahoma, and a portion of Texas.

F. L. MOSELEY CO. has completed a new 30,000 square-foot manufacturing facility in Pasadena, Calif. The plant, which represents a major step in Moseley's expansion program, is located at 45 Eureka Street.

BABCOCK & WILCOX CO. has named **R. K. Mack** works manager and **W. S. Lanier**

Answers to "A Short Course on Labor Law"

Page 274

1. True.
2. True.
3. True.
4. True.
5. True.
6. True.
7. True.
8. False.
9. True.
10. True.
11. True.
12. True.
13. True.
14. False.
15. False.
16. False.
17. True.
18. True.
19. False.

Free Book Catalog

For a free copy of our book catalog write to BOOK DEPARTMENT, GULF PUBLISHING COMPANY, P. O. Box 2608, Houston 1, Texas. Often books reviewed here may be purchased from this source.

New handy refractory guide

Here are a few of the technical factors covered...

Abrasive qualities
Acid resistance
Coefficient of expansion
Composition
Compressive strength
Conductivity
Drying shrinkage
Fusion point
Modulus of rupture
Selling properties
Temperature limit

SEE OUR CATALOG IN REFINERY CATALOG OR SEND FOR A COPY

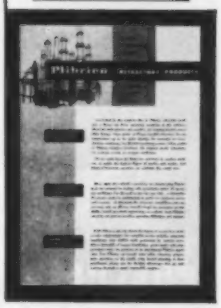
All the facts you need to select the right refractory for every operating condition in the refinery industry

Every physical and performance characteristic of refractories specially selected from Plibrico's complete line is charted for your quick reference.

You'll find grades of Plicast castable refractory with exactly the properties you need...the temperature range, the abrasion resistance, the insulation value. You'll also find select grades of the original plastic refractory, Plibrico Jointless Firebrick, for *any* operating condition.

See how Plibrico provides unified responsibility through complete service...including products, engineering and installation.

WRITE FOR FREE REFERENCE CHART #76 giving detailed data on products for refinery process linings or consult your local Plibrico Field Engineer for technical assistance.



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Plibrico Sales and Service Throughout the World

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For more data on advertised products, use Readers' Service Cards, last page.

Suppliers . . .

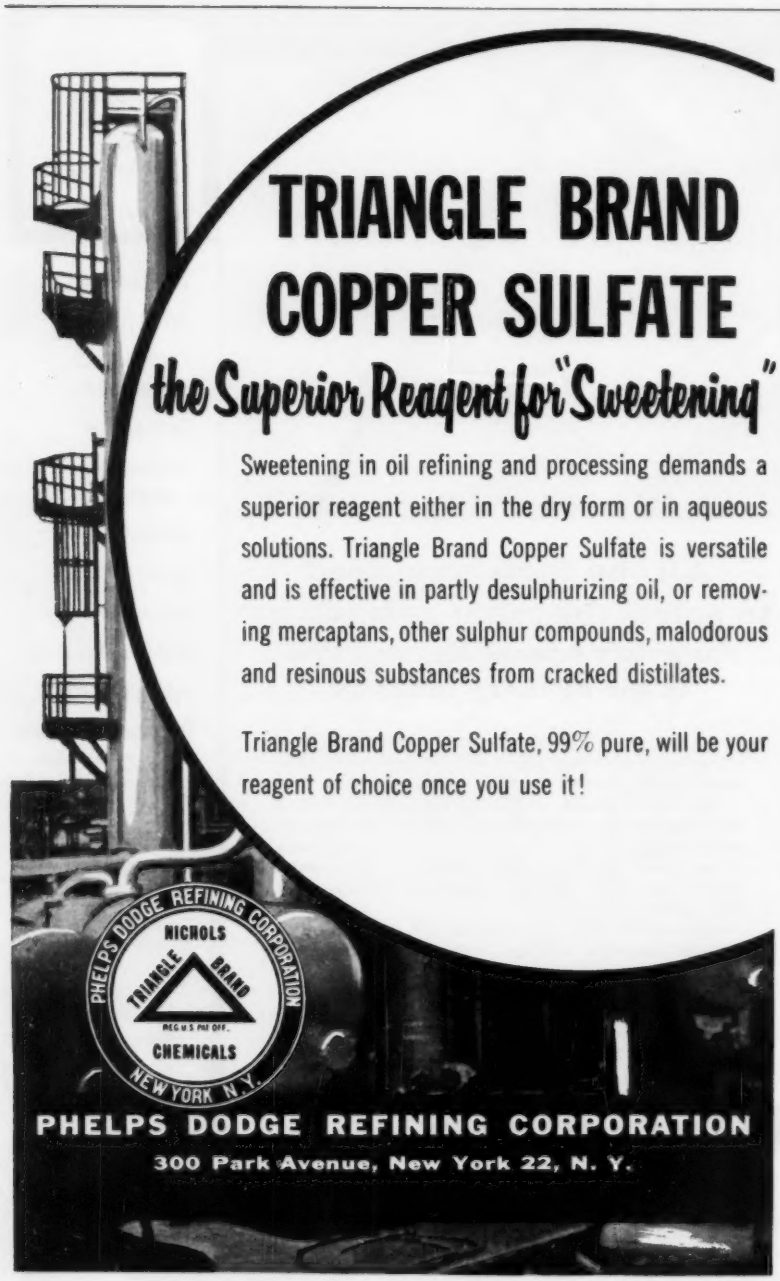
Mack

Lanier

superintendent, Augusta, Ga., refractories plant. Mack, who has been Augusta plant superintendent since 1953, joined B&W in 1937. Lanier joined the company in 1932.

THE CONNECTICUT HARD RUBBER CO. has completed arrangements to buy the assets of California Rubber Products, Inc., Torrance, Calif.

OAKITE PRODUCTS, INC., has appointed **Harlis E. Martin, Charles W. Pearce,** and **Frank T. Mountjoy** technical service representatives.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Sweetening in oil refining and processing demands a superior reagent either in the dry form or in aqueous solutions. Triangle Brand Copper Sulfate is versatile and is effective in partly desulphurizing oil, or removing mercaptans, other sulphur compounds, malodorous and resinous substances from cracked distillates.
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INDUSTRY QUIZ

(Answers to Quiz on Page 20)

1. There are currently 15 producers of polyethylene resins in the United States. ("Polyolefin Processes Today," page 162).

2. The three major U. S. polyethylene producers rate: 1. Carbide, 2. USI, and 3. Du Pont. ("Polyolefin Processes Today," page 162).

3. Polypropylene is the lightest plastic, with a specific gravity 0.90. ("Polyolefin Processes Today," page 162).

4. More than 5 years elapsed. It was not until 1938 that the first ton had been produced. ("Polyolefin Processes Today," page 162).

5. Capacity is expected to reach 1.78 billion pounds by 1961 for all types of polyethylene in the United States. ("Polyolefin Processes Today," page 162).

6. True. With less fuel required for heavier feeds, less hydrogen is produced in partial combustion, and less hydrogen goes into the products from the acetylene-producing reaction. Look again at the other variables in "Which Acetylene Process is Best?," page 223.

7. False. Polymerization-grade isoprene must have impurity levels in the low parts per million. You'll find other important factors affecting isoprene in "What Isoprene Route is Best?," page 227.

8. Isoamylenes, by dehydrogenation, yield *isoprene,* the monomer for the new synthetic natural rubber, *cis*-1, 4 polyisoprene. See a complete description and pilot-plant results for this new process in "New Process for Pure Isoamylenes," page 229.

9. False. It is often possible to get better control response if a nonlinear element is added to an otherwise linear process-control system. Learn how to handle nonlinear systems in "Automation Today," Part 23, Page 247.

10. Each 1,000 gallons costs 21 cents. See the chart giving treated water costs for 16 different combinations of ion exchange systems in "How to Select Demineralization Systems," page 261.

11. Labor and management have trouble agreeing because most spokesmen are committed people who prefer group loyalty to solving the problem, according to "Why Problem-Solving Between Groups Sometimes Fails," page 269.

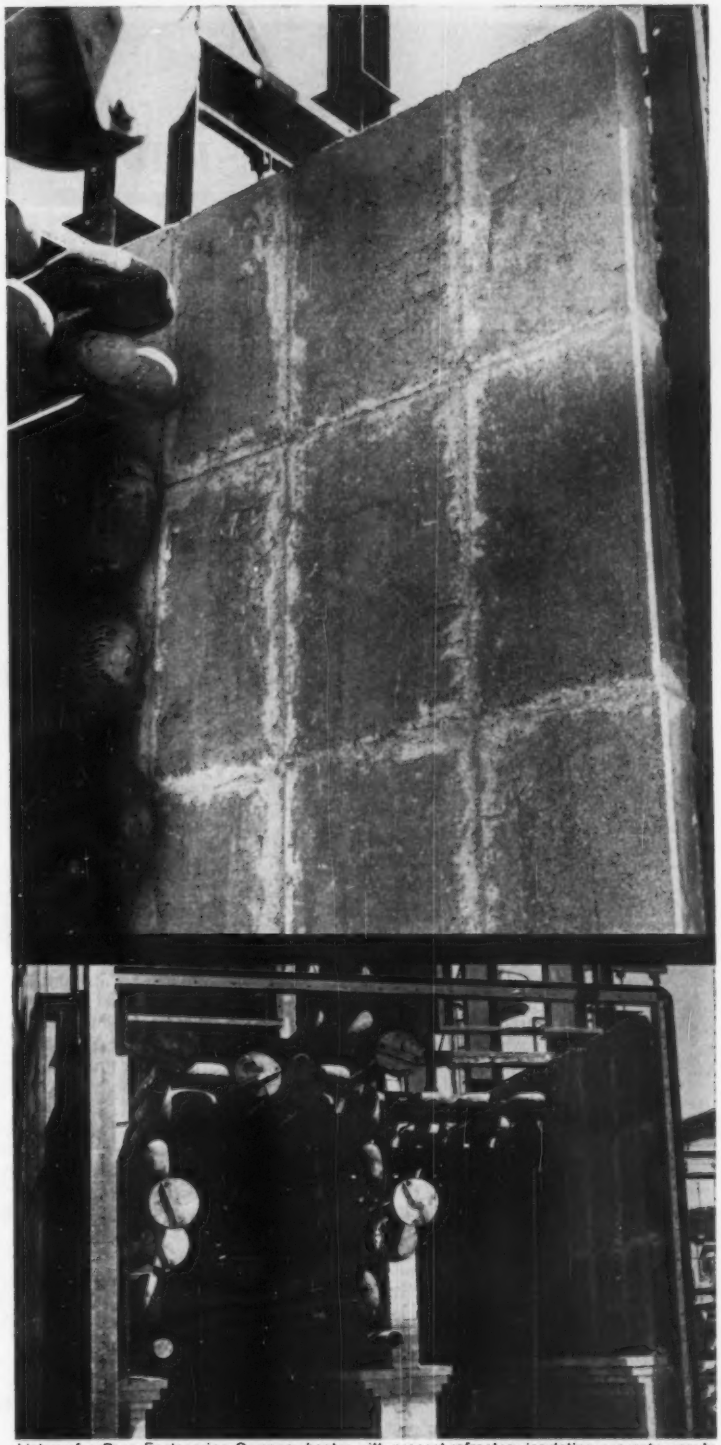
Refractory concrete protects while it insulates

For heater linings, refractory concrete made with LUMNITE calcium-aluminate cement and suitable aggregates offers two vital services. It provides a dependable heat-resistant layer for structural steel parts, and it insulates the unit to reduce heat loss (and fuel costs).

Linings of refractory concrete are light in weight, yet structurally strong through a wide temperature range. Placement is easy and economical, since refractory concrete made with LUMNITE cement can be precast, gunited, poured or troweled into place. In any case, service strength is reached within 24 hours.

For extra convenience, castables containing LUMNITE cement are available from leading manufacturers of refractories. These packaged mixtures are ready to use with just the addition of water. For more information, write Universal Atlas Cement, 100 Park Avenue, New York 17, N. Y.

L-206 "USS," "Atlas" and "Lumnite" are registered trademarks



Lining of a Born Engineering Company heater with precast refractory insulating concrete panels made with LUMNITE calcium-aluminate cement and expanded insulating aggregates. Installed by Blaw-Knox Company at Ashland Oil & Refining Company, Canton, Ohio.

Universal Atlas Cement
Division of
United States Steel

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For more data on advertised products, use Readers' Service Cards, last page.

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MISCELLANEOUS

■ IMPORT QUOTA—We seek Coastal Refiner wanting 1961 quota available now on contract. Bonus $1.10 level. Box 4803; Midland, Texas.

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Permanent employment with an expanding company. Excellent advancement opportunities for men with at least 10 years experience in process design of petroleum and petro-chemical plants.

Send detailed resume to:
G. VICTOR HOPKINS
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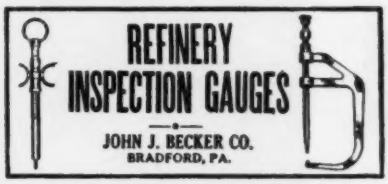
2300 Chester Ave. Cleveland 1, Ohio

NOTICES SERVICES

■ LINES WANTED by manufacturers agent now contacting refineries, petrochemical plants, pipeline companies, etc. in Texas, Louisiana, etc. Please send details to Box 8213, Houston 4, Texas.

FOR SALE



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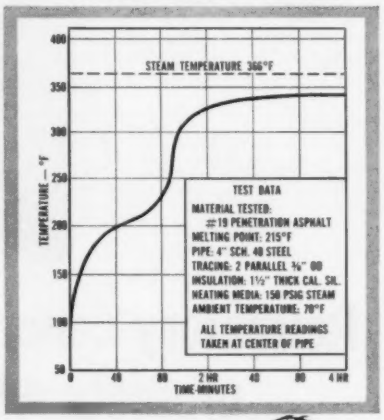
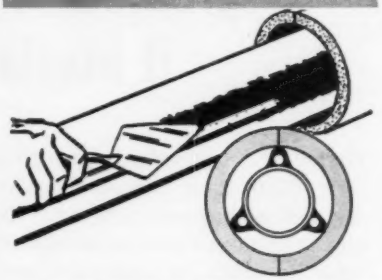
Colorado Oil Shale

Crushed to minus 8-inch

Write: Commercial Development Division
Union Oil Company of California
P. O. Box 76
Brea, California

Eliminate Asphalt heating problems with THERMON HEAT TRANSFER CEMENT





On seventy miles of asphalt line, some fifty refineries have used Thermon Heat Transfer Cement to eliminate the physical problems and expense of internal tracing and steam jacketing. A non-metallic, adhesive compound with highly efficient heat transfer characteristics, Thermon Heat Transfer Cement used on asphalt lines and equipment

Eliminates stuffing boxes and packing glands

Eliminates the possibility of cross contamination

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Eliminates misfitted prefabricated jacketed piping.

Thermon can be used successfully on pumps, valves, pressure and differential pressure transmitters, flow measuring instruments, lab apparatus and pilot plant equipment in service with wax, lube oil, heavy greases, alkylates and #3-#90 penetration asphalt.

For existing or future asphalt installations, investigate the benefits of Thermon, the *proved* solution to heat transfer problems.

Write for Thermon Engineering Data.

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Test Yourself
(Answers to Quiz on Page 276)

CASE NO. 1

Arbitrator Arvid Anderson ruled: "No absolute right of union representation exists at any time that management wishes to discuss some matter with an employe. However, when a grievance has been filed or when an employe has reasonable grounds for believing that the company is considering disciplinary action, the worker has the right of union representation. Propet's refusal to perform certain work and the declaration of the foreman that he was reporting such fact to his superiors gave Propet reason to believe that disciplinary action might result during the conference. Under these circumstances Propet properly refused to participate in a conference with the superintendent without union representation."

CASE NO. 2

Arbitrator Freeman F. Suagee ruled: "The application of superseniority in instances of layoff is well known and accepted. The purpose of giving committeemen and stewards superseniority is to insure continuity in administration of the collective-bargaining agreement. . . . The unusual fact in this case is the election of Calton to the Bargaining Committee while on *layoff*. The sole question is whether, by virtue of election to the Bargaining Committee, a laid-off employe must be recalled immediately.

"There is nothing in the agreement supporting the union claim that the grievant must be recalled immediately because he was elected. Once a layoff is made and the employe is away from the job (six weeks in this case) the purpose of super-seniority ceases. If the laid-off employe cannot function as a representative because he is on layoff the company is not obligated to help the union. Grievance denied."

CASE NO. 3

Arbitrator Joseph M. Klamon ruled: "Seniority provides preference for jobs only where jobs exist. If jobs are eliminated, changed or otherwise become unavailable, seniority offers little protection to the employe. Duties of the new jobs were totally dissimilar and utilized a higher degree of skill. Therefore the company had every right to require employes to pass certain tests in order to qualify for the new production line. The new jobs did not require the skills of the senior employes, and thus did not have to respect their seniority."

WILFLEY ACID PUMPS

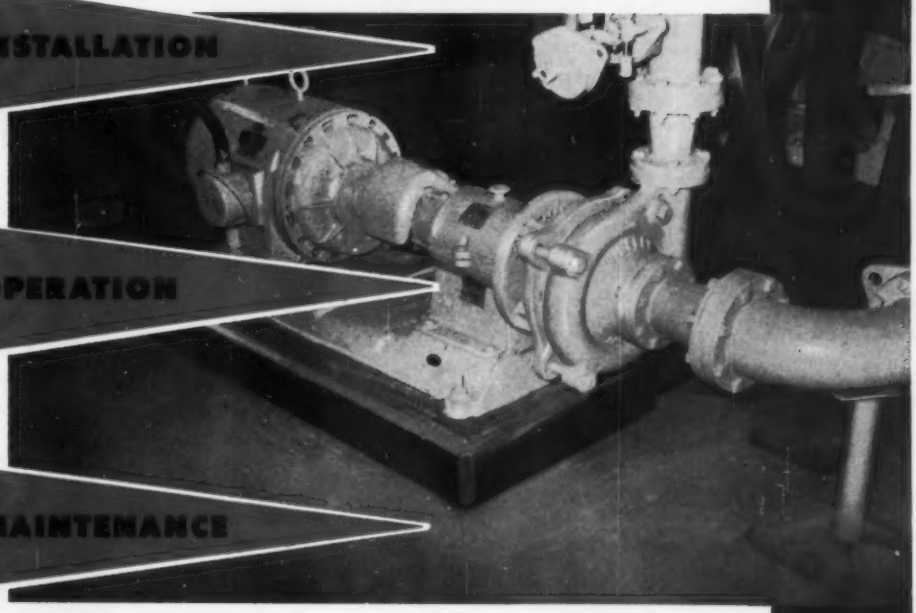
Dollar-Saving Efficiency

THROUGH

Low Cost INSTALLATION

Low Cost OPERATION

Low Cost MAINTENANCE



The built-in economy features of Wilfley Acid Pumps guarantee you low cost pumping of corrosives, hot liquids and mild abrasives. Wilfley gives you low installation cost for the pump, and, for maximum pumping economy, each installation is job engineered.

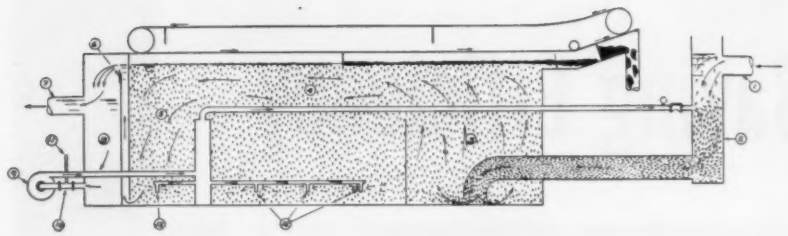
Rugged, simple frame construction and packingless design guarantee trouble-free, 24-hour service without attention. Long wearing parts, few in number, are available in a variety of metal alloys as well as plastic. Wilfley offers you a wide range of pump sizes and capacities.

Wilfley Sand Pumps
"Companions in Economical Operation"
Wilfley Acid Pumps

For lower pumping costs, higher output, longer pump life —specify Wilfley Acid Pumps.

A. R. WILFLEY and SONS, INC.

DENVER, COLORADO, U.S.A. P.O. BOX 2330
NEW YORK OFFICE 122 EAST 42ND STREET, NEW YORK CITY 17, N. Y.



Legend

1. Inlet
2. Inlet Riser
3. Parallel Flow Zone
4. Lateral Flow Zone
5. Counter Flow Zone
6. Discharge Weir
7. Discharge
8. Clarified Water Zone
9. Ingersoll-Rand Centrifugal Pump
10. Air Induction Assembly
11. Air Intake
12. Air-Water Mixture Discharge

Refinery Waste Clarifier Works on Unusual Principle

Water is clarified from industrial waste with a minimum of liquid retention

One of the basic rules for a liquid moving system employing a centrifugal pump is to have an air-tight suction. Centrifugal pumps are not designed to operate on an air-water mixture.

Fully aware of this, the designers of the Gibbs flotation system for clarification of refinery waste water take a great deal of pains to introduce as much as 2 cubic feet of air per minute into a standard RVNL Motorpump recirculating 400 gpm.

The Gibbs unit, manufactured by Komline-Sanderson Engineering Corp., Peapack, N. J., works on an exactly reverse principle to the more conventional settling processes.

To clarify liquids by settling, the suspended particles must have a specific gravity greater than that of the liquid. Depending on the ratios of the gravities, a considerable time element of liquid retention is necessary. In flotation, the ratios of the gravities is reversed by the attachment of tiny air bubbles to the suspended particles, causing them to rise rapidly to the liquid surface where they are skimmed off.

In petroleum refinery and chemical processing wastes involving keytones, acetones, chlorinated hydrocarbons, acidic oils, organic suspensions, etc., the particles settle very slowly or persist in remaining in suspension indefinitely. Most of these suspensions or emulsions can be readily floated with the lifting power of tiny air bubbles.

The air bubbles are generated without the aid of a compressor. A venturi section is provided immediately in front of the pump intake. The throat of the venturi is formed by a porous artificial stone tube with a wall thickness of ⅜ inch. The air intake is open to the atmosphere, restricted only by a needle valve to permit reduction in the volume of air if desired.

Suspended particles are subjected to impingement of the air bubbles three times between the inlet and the outlet of the flotation unit. The air-water mixture circulated by the motorpump (9) is discharged into the liquid at the inlet (2) and in the lateral and counter flow zones (12). The treatment produces clarified water from industrial waste with a minumum of liquid retention. Flow rates of 3 to 4 gpm per square foot of floor space are standard in these waste clarification systems. Ingersoll-Rand Co.

Circle E1 green card, last page

Teflon Raschig Rings Resist Sludge Build-Up

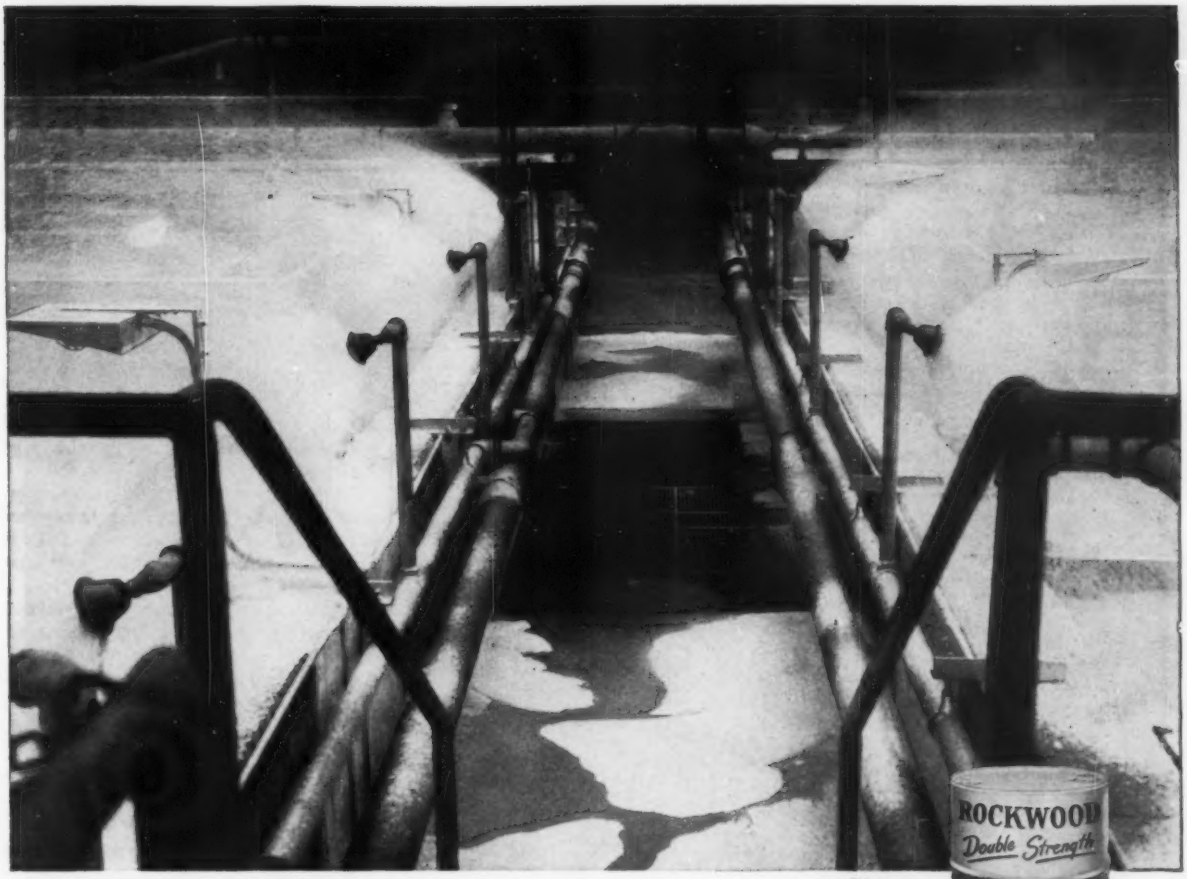
Fluoroflex-T (Teflon) Raschig Rings resist tendencies of sludges, suspended or precipitated solids and contamination products to build up and restrict flow. They are particularly suited for HF and other acid processes at temperatures to 500°F.

These chemically inert tower packings provide maximum product purity and maintain more uniform flow rates in mass transfer for longer periods than conventional materials.

The thin wall design of Fluoroflex-T Raschig Rings combines optimum stiffness with light weight for maximum economy.

Standard Raschig Rings are available in ⅝-inch, ¾-inch, 1-inch and 1¼-inch nominal OD. Other sizes are available on request. Resistoflex Corp.

Circle E2 green card, last page



Testing a Rockwood FogFOAM System that guards the oil separator pits in Cincinnati Gas & Electric Co.'s plant.

Double Strength FOAM Liquid Gives Double Protection. Three parts of Rockwood Double Strength FOAM liquid mixed with 97 parts of water and 900 parts of air form a fire-smothering blanket that quickly reseals itself. You pay for only three parts per thousand for this extinguishing agent that has proved its ability to put out spill fires in flammable liquids, with maximum speed and safety for personnel. Tested and listed by Underwriters' Laboratories, Inc. Branch Offices in all principal cities.

Here's high protection *against* low flash-point fires!

In any group of oil separator pits, the pit with the lowest flash point sets the danger mark for the entire area.

To installations of this type — and to many others endangered by fire — Rockwood FOAM and FogFOAM systems bring the surest, most dependable fire protection ever developed.

In the FogFOAM system shown above, protection starts with the heat detectors located around the pits. During any critical temperature rise these detectors sense the inception of fire. The signal is transmitted automatically — and the FogFOAM system goes into instant action.

Rockwood FOAM liquid, mixed with water and air, is then released through many FogFOAM heads over each pit. Within a few seconds a thick blanket of Rockwood FOAM completely covers the threatened area . . . *A disastrous fire has been prevented.*

Fire protection systems are custom engineered by Rockwood to meet the needs of every type of oil and gas installation. Send the coupon for details.

ROCKWOOD SPRINKLER DIVISION

of The Gamewell Company • Subsidiary of E. W. Bliss Company

Engineers Water... to Cut Fire Losses

Distributors in all principal cities

ROCKWOOD SPRINKLER DIV.
of The Gamewell Company
A Subsidiary of E. W. Bliss Company
505 Harlow Street
Worcester 5, Mass.

Please send me information on Rockwood fire-fighting products and systems.

Name.....

Title.....

Company.....

City.....*Zone*..*State*.....

For more data on advertised products, use Readers' Service Cards, last page.

New Equipment . . .

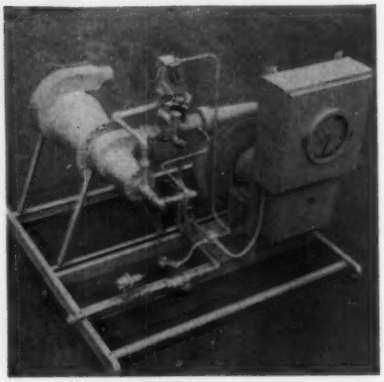
Direct-Fired Air Heater Delivers 10 Million Btuh

Extremely high combustion efficiency and absence of impurities are principal features of "Q"-PAK—a new packaged direct-fired air heater. Basic uses include heating of process air for fluidized bed dryers, direct heating of furnaces, indirect heating of process fluids, packaged waste disposal units, and packaged multi-stage chemical reactors.

Heart of the heater unit is the unique UNIFLUX Fuel Reactor—a high intensity mixer in which combustion air is brought tangentially into an annular space around a combustion chamber. This produces a cooling effect and enables the fuel reactor to be constructed entirely of metal.

Controls are simple on the heater because the fuel reactor has excellent stability through a wide range of air-to-fuel ratios—from 50 percent stoichiometric to 100 times theoretical air requirements without loss of flame.

The flame is contained in the reactor due to heat release rates up to 10 million Btu per hour per cubic foot of combustion volume. However, there is little measurable heat loss in the non-insulated chamber. This can be exhibited by placing the hand directly on the outer shell with heated air outlet temperatures as high as 3,000°F.



The absence of refractory lining permits immediate response to changing temperature requirements—up to 3,000°F. It also allows reaching the desired temperature within seconds after ignition.

"Q"-PAK is immediately available in sizes ranging from 100,000 Btu per hour to 10 million Btu per hour heat release. The delivered unit is ready for immediate operation—only fuel and electrical supply hookups are required. Black, Sivalls & Bryson, Inc.

Circle E3 green card, last page

First Literature Available On New Compressor Model

A new four-page brochure, describing the operating characteristics of the company's 200-1,000 hp EM compressors is the first literature published on this unit.

The booklet also describes EN-Tronic controls which can make the EM compressor into a completely automatic unit which starts itself, shuts itself down and can operate fully-unloaded.

Other specifications reviewed are:

- rpm - 514
- bhp - maximum - 1,000
- Number of throws - 2 or 4
- Stroke (inches) - 9

The brochure, fully-illustrated, contains a cut-away model of the entire unit showing internal mechanisms, a page of charts and diagrams, as well as complete specifications tables. The Cooper-Bessemer Corp.

Circle E4 green card, last page

Clad Metal Tube Sheet Standards Proposed

To help establish long-needed standards for clad metal tube sheet, the company has submitted an engineering specification on copper and copper alloy clad steel plate for study by interested segments of industry. These products are of prime importance for corrosion control and high heat exchange efficiency in boilers, condensers, steam generators and similar heat transfer equipment. After industry acceptance, the proposal entitled: "Tentative Specification for Copper and Copper Base Alloy Clad Steel

A RECORD CLIMBING TO THE TOP

the KEMCO code / THOROUGH QUALITY CONTROL INSPECTION SPECIFICATIONS MATCHED EXACTLY DELIVERY WHEN PROMISED

We'd like to furnish you more information. Please write today for illustrated brochure and additional data on personnel, facilities and customers to:

KRUEGER ENGINEERING & MANUFACTURING CO.
12001 HIRSCH ROAD • HILLCREST 2-2537
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LU 4-6651
Tulsa, Okla.

For more data on advertised products, use Readers' Service Cards, last page.

1800° IS NOT TOO HOT FOR NEW CALSILITE-HI

New Ruberoid Calsilite-Hi insulation for soaking heat to 1800°F. It's light, strong and so economical it can be used on all types of jobs. Calsilite-Hi is ideal for both insulation and fireproofing.

Calsilite-Hi, a molded calcium silicate insulation, extends the Ruberoid insulation line to the upper temperature limit of 1800°F. Available in half-sectional, three segmental and block form, it can be used as fireproofing for walls, partitions and ceilings as well as insulation for piping and equipment.

Calsilite-Hi is light and easy to install. It cuts and mitres quickly, smoothly and is gentle on hands. What's more, it keeps its strength even when wet, does not soften or fall off. Returns to its original thermal efficiency when dry. Resists most chemicals and alkalis in industrial concentrations.

For additional specifications or samples of Calsilite and Calsilite-Hi insulation, write: The Ruberoid Company, 500 Fifth Avenue, New York 36, New York.

THERMAL CONDUCTIVITY
(BTU/sq. ft./inch/hr./°F.)

400°F. (Mean)	0.54
600°F. (Mean)	0.64
800°F. (Mean)	0.74

Density 13.5 lbs. per cu. ft.

Compressive Strength
5% deformation (Min.) 135 lbs. psi.

Flexural Strength 75 lbs. per sq. in.

Change under Soaking Heat
24 hrs. @ 1800°F.

Loss in weight	5%
Linear Shrinkage	1.5%

The RUBEROID Co.®

For more data on advertised products, use Readers' Service Cards, last page.

More equipment manufacturers choose Fast's Couplings than any other gear-type coupling

Leaving other claims aside, the thing that counts in couplings is customer confidence—and industrial equipment manufacturers have made Fast's their overwhelming choice. The Fast's line is more diversified, too—in a complete range of sizes and types for shafts, from ½" to 32" and larger.

Every Fast's Coupling brings you superb engineering only the original gear-type coupling can deliver. Smooth-running units that are designed to outlast the machines they connect. Rapid service from experienced field engineers backed by outstanding stock facilities. Write today for full details on couplings to suit your needs to: KOPPERS COMPANY, INC., Fast's Coupling Dept., 1511 Scott St., Baltimore 3, Maryland.

KOPPERS

FAST'S COUPLINGS

Engineered Products Sold with Service

THERMEL® electric preheaters ...FOR PIPE WELDING

Temperature range from ambient to 600° F.

Quick clamp clevis fastening. Waterproof construction.

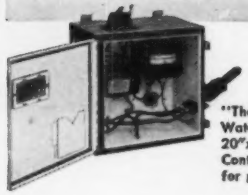
Heaters available from 3" O.D. pipe through 20" O.D. pipe.

Standard voltage 230/240V — others available.

Equipped with heavy duty grounded plug and cable for use with "*Thermatrol*" Controls.

Available in Thermastrip types (shown in photo) or in cast aluminum or cast bronze styles.

Write for details.



"Thermatrol" Waterproof cabinet 20"x20"x12" deep. Control for Preheaters for pipe welding.

Thermel INCORPORATED

9416 ROBINSON ROAD
FRANKLIN PARK, ILL.

New Equipment . . .

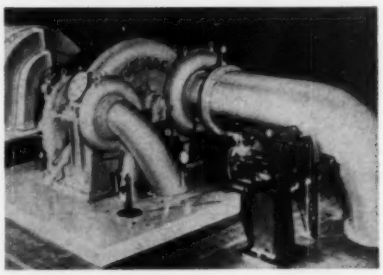
Plate," will be evaluated for acceptance by the ASTM, SAE and appropriate technical societies.

The specification establishes minimum standards for physical and mechanical properties, cladding method, chemical composition, test procedures, inspection and dimensional variations for circular and rectangular clad plate. Copper and copper alloys covered for cladding with carbon steel and low alloy steel include: Electrolytic tough-pitch copper, oxygen-free copper, deoxidized high-phosphorous copper, Muntz metal, naval brass, admiralty metal, 70-30 copper-nickel alloy, 90-10 copper-nickel alloy and Monel. Copies of the specification are available. Bridgeport Brass Co.

Circle E5 green card, last page

Air Compressor Is Both Lighter and More Compact

The most efficient four-stage, integral-gear centrifugal air compressor ever offered in the U.S., both lighter and more compact, is virtually vibration free because of its stiff shaft design which operates below the critical speed. The integral gear allows direct coupling to



a low-speed motor driver which eliminates a high-speed coupling and results in minimizing installation problems.

The simplified construction and lubrication of the new design provide quiet, lower maintenance unit, which is backed by the Worthington service and parts organization. The units will be available in air-inlet capacities ranging from 4,000-30,000 cubic feet per minute and discharge pressures of 60-105 psig. Worthington Corp.

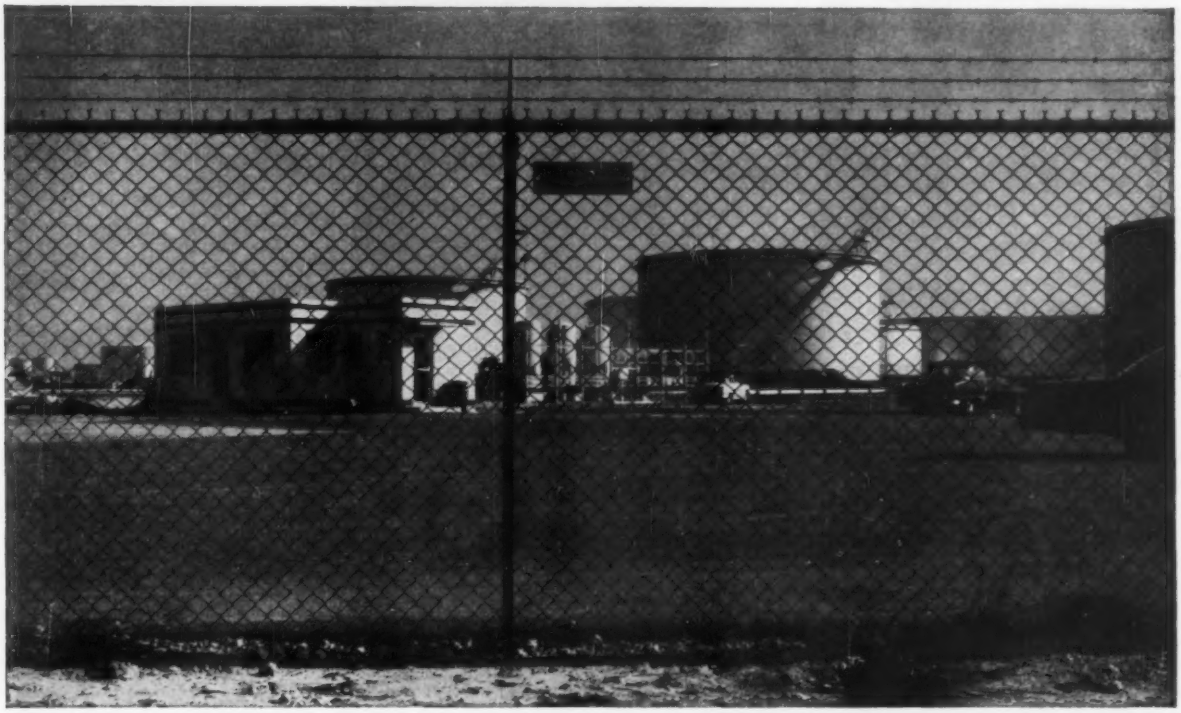
Circle E6 green card, last page

No Oil in Air Stream With Non-Lube Air Compressor

A new, non-lube air compressor designed for continuous heavy duty service in applications where lube oil contamination of the air stream cannot be tolerated has been designed. The unit is a balance-opposed type compressor driven by a flange-mounted electric motor.

Piston rings and piston rod packing in the compressor cylinder are made of self-lubricating Teflon. The non-lube cylinder is connected to the crankcase by

Specially engineered gates. Every Cyclone gate is just as sturdy, durable and non-climbable as the rest of the fence. They're mounted on heavy posts . . . equipped with solid hinges and catches . . . and have the closest precision in the locking device.



USS Cyclone Steel Fence keeps your private property private

Thieves, vandals and trespassers know better than to try getting past a USS Cyclone Steel Fence. This rugged, 24-hour watchman protects valuable property and equipment as no *human* watchman can. Cyclone also keeps children from playing on the premises . . . averts possible damage suits resulting from accidents. It's tough, strong, fire- and corrosion-resistant—built to stand indefinitely with very little maintenance. USS Cyclone Steel Fence will keep *your* private property private. Write to American Steel & Wire, Dept. 0457, 614 Superior Avenue, N.W., Cleveland 13, Ohio.

USS and Cyclone are registered trademarks

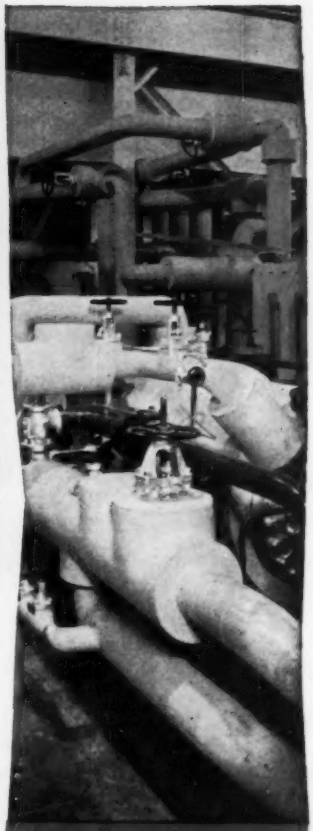
Where security counts, count on USS Cyclone Fence

American Steel & Wire Division of United States Steel

Cyclone sales offices coast to coast

For more data on advertised products, use Readers' Service Cards, last page.

Complete control
of temperatures with
PABCO
PRECISION-MOLDED
CALTEMP
a Calcium Silicate
Insulation



INSULATION GUIDE	
Temperature	Recommended Pabco insulation
to 600° F.	85% Magnesia pipe covering • block • cement
to 1200° F.	Caltemp pipe covering • block • cement
to 1500° F.	Prasco 18 C pipe covering • block • cement
to 1900° F.	Prasco 18 C block

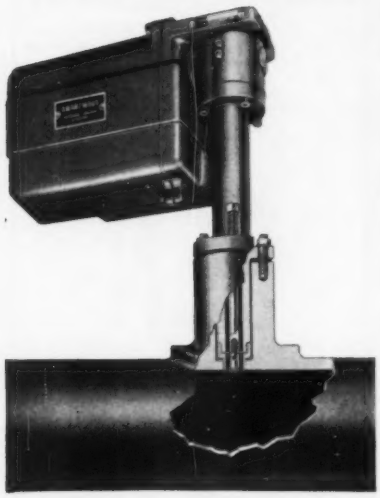
Name your temperature. A performance-proved Pabco pipe or block insulation will maintain it at economical levels up to 1900° F. With Pabco Caltemp, 85% Magnesia, or Prasco Insulations, heat losses are reduced to an absolute minimum . . . finest performance assured. For data on technical advantages, case histories, or engineering consultation . . . write . . . or contact one of Pabco's insulation engineers.

PABCO INDUSTRIAL INSULATIONS DIVISION

Fibreboard Paper Products Corporation • San Francisco 19 • Chicago 54 • Houston 4 • New York 16 • Los Angeles

Great things are happening in AutroniC® Control

TOUGH PROBLEMS ARE NO PROBLEM



FOR THIS FOOLPROOF, FOUL-PROOF PRESSURE TRANSMITTER

Here is a primary sensing element for those tough jobs you'd like to forget. Mounted right on the process pipeline or tank, the Swartwout Flush Diaphragm Pressure Transmitter will effortlessly measure pressure or liquid level of polymers, slurries, asphalts, viscous fluids, molten metals and other difficult media. No stagnant pressure lines, no steam jacketing necessary . . . the stainless steel transmitter diaphragm fits flush with the inside of the vessel.

A friction-free linkage multiplies diaphragm motion and actuates the core of a differential transformer to produce a 0-0.5V AC signal for any Swartwout AutroniC indicator, recorder or controller. Sensitivity is better than 0.005%, reproducibility 0.1%, accuracy 1.0%.

The Flush Diaphragm Pressure Transmitter is just one unit in the constantly-growing AutroniC family of electronic instrumentation . . . a family that includes all necessary components for complete electronic control of any process parameter.

For details on the Flush Diaphragm Pressure Transmitter, request Bulletins A-713 and A-718. Swartwout Division, Crane Co., Hooksett Industrial Park, Manchester, N.H.

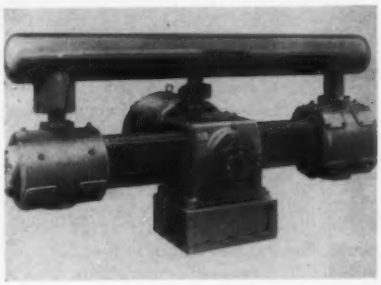
SWARTWOUT

. . . world leader in electronic process instrumentation

S.A. 1958

New Equipment . . .

an extra long distance piece which is internally divided into two compartments by a baffle plate which houses oil scraper piston rod packing. This arrangement isolates the compressor cylin-



der from the main compressor lubrication system. To further prevent lube oil contamination of the compressor piston rod and piston rod pressure packing, an oil slinger is placed on the rod between the oil scraper packing and the pressure packing. The rod itself is chrome-plated to eliminate the possibility of corrosion from cooling water which is passed through the pressure packing and circulated around the surface of the rod.

The non-lube compressors are furnished as completely packaged units with motor and intercooler in position, ready to operate. The machines are almost vibrationless in operation and can be mounted anywhere. Foundations need only be large enough to support the weight of the compressor. Clark Bros. Co.

Circle E7 green card, last page

Cause and Cure of Wood Failure in Cooling Towers

Causes, symptoms and suggested cures for deterioration of wood in cooling towers are described in an eight-page reprint presented in two parts.

The first part describes the three principal types of deterioration found in wood towers—leaching, delignification, and microbiological attack—and tells how they can be discovered by inspection.

The second part outlines corrective measures that can be taken to provide effective control of the three types of attack. The reprint is fully illustrated, and contains a diagram that points up potential locations of wood deterioration in a cooling tower. Nalco Chemical Co.

Circle E8 green card, last page

Electric Control System Described in Brochure

A new four-page, illustrated brochure describes the 720 solid-state electric control systems which are designed to produce process variable outputs in accordance with desired or set point conditions.

The system, which is a combination

PUTNAM

SPECIFY - - - *for lower piping system cost— higher efficiency*

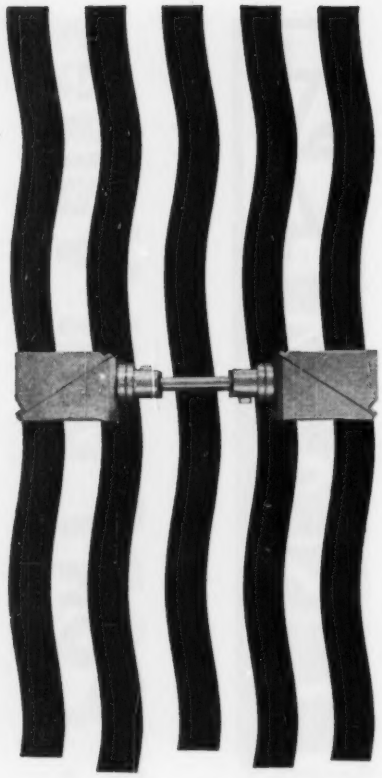
FULL PORT Ball Valves

We'll be glad to tell you more, write

The J. L. Putnam Company, Inc.

SMITH STREET

BIDDEFORD, MAINE



for measuring color in continuous streams

Beckman Model 77 Continuous Turbidimeter-Colorimeter takes the guesswork out of clarity and color determinations... gives rapid, accurate readings to better than ±2% of light transmission. The Model 77 consists of an Analyzer Unit and Control Unit... precision designed and ruggedly constructed to bring colorimetry to continuous process applications. Among the wide range of applications are control of water and industrial waste treatment processes, and colorimetric quality control analyses in the production of chemicals and petroleum. ☒ Outstanding Beckman features are: ±1% repeatability... push-button scale expansion from 0-100% to 0-50% transmittance... wavelength ranges from 350 to 1000 mμ. ☒ Complete information applicable to your specific process is available from your nearest Beckman Sales Office. Or write direct for Data File 25-11-13.

Beckman
Scientific and Process Instruments Division
Beckman Instruments, Inc.
2500 Fullerton Road,
Fullerton, California

INSTRUMENTAL IN YOUR FUTURE 25 YEARS 1935-1960

New Equipment . . .

of electrically and electronically-operated devices, utilizes such primary measuring elements as thermocouples, strain gages, resistance temperature detectors or moveable core transformers. Measuring signals are transmitted through control signal manipulators to either electrically-operated control or pneumatically-operated control drives or valves.

Specific functions of the Bailey systems are listed and system design packaging and construction are explained through the use of block diagrams and component illustrations.

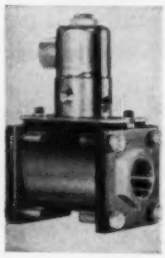
The new brochure discusses signal range, measuring signal initiators, control action units, selector stations, power units, electric drive, pneumatic drives and valves, and electric-to-pneumatic conversion. Bailey Meter Co.

Circle E9 green card, last page

Valve Operates on New Unique Squeeze Principle

A new Tube-O-Matic valve works on a completely different concept in valve design and operating characteristics.

Unique squeeze action automatically controls the flow of air, oil, chemicals and even grinding slurries, without the use of poppets or spools. There are no metal-to-metal contacts and no metal-to-rubber seals. This maintenance-free construction makes the valve particularly suitable for the petroleum and petrochemical industries where contaminated fluids and gases present a problem.



When the valve is open, supply pressure through the inlet port forces an elastic rubber sleeve against the tube, forcing the fluid to flow around the inlet plug and through the outlet port.

To close the valve, pilot pressure is applied between the inside diameter of the tube and the outer periphery of the rubber sleeve. This collapses the sleeve over the rounded ends of the inlet and outlet and plugs, sealing off the supply pressure. The only action is the flexing of the sleeve.

Pressures up to 200 psi can be handled. Pipe sizes: ¼-inch to 12 inches. The valve is available either normally open or normally closed. Airmatic Valve, Inc.

Circle E10 green card, last page

Gas Chromatograph Uses Tape Program for Precision

Tape programing, used for the first time to achieve greater precision and flexibility in process stream analysis by

CRY-O-GEN-ICS

YOUR KEY TO MORE PROFIT

In the petroleum and petrochemical industries, new applications of cryogenics (low temperature separation) are opening the way to more profits.

Interested in low cost production of oxygen, nitrogen, argon, methane? purification or liquefaction of gases? Think *first* of Messer!

Write for *free illustrated brochure.*

Messer

AMERICAN MESSER CORPORATION
Chrysler Building, 405 Lexington Ave.
New York 17, N.Y.

INSTRUMENTATION FOR AUTOMATION

Now, with 12 standard ranges, General Electric Mass Flowmeter

PERFORMANCE PROVED

. . . ON THE LINE! Today, many companies in the petroleum, chemical, petrochemical and natural gas industries are accurately measuring valuable process fluids directly in pounds with the General Electric True-Mass Flowmeter.

For example, these 12 applications have been performance-proved in actual service metering:

- **air • natural gas • alcohol • vinyl chloride**
- **freon • penicillin • liquid carbon dioxide**
- **ethylene • liquid petroleum gas • naphtha**
- **jet fuel • methane hydrogen mixtures**

(Many more to come—let us know what your specific application is.)

NEW ACCESSORIES FOR APPLICATION FLEXIBILITY:

Now, you can control batch blending accurately on a system basis with this flowmeter and new accessories which include:

counters—permit remote digital readout; **pre-set counters**—for automatic blending; **ticket and tape printers**—allow permanent and remote recording of flow.

AND *ALL* MODELS FEATURE:

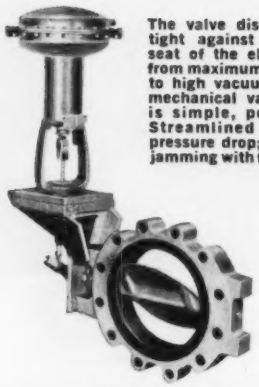
- Accuracy independent of variations in density, pressure, viscosity and temperature
- Completely self-contained, self-integrating unit
- Low pressure drop
- Accuracy unaffected by fluctuation in power supply voltage and frequency
- Long-term stability for minimum maintenance and infrequent field calibration
- Quick response to rapid changes in flow without overshoot or lag
- Measurement in pounds—eliminates tedious conversions

DO YOU HAVE AN APPLICATION for this revolutionary new instrument? Chances are you do, and we'd like to know about it. Contact your nearby G-E Sales Office, or write directly to General Electric Co., Section 599-03, Schenectady 5, N. Y. Be sure to ask for bulletin GEA-6925A. In Canada, contact Canadian General Electric Co., 940 Lansdowne Avenue, Toronto 4, Ontario. On applications in the natural gas industry, contact Black Sivalls and Bryson, Inc., P.O. Box 1714, Oklahoma City, Okla.

INSTRUMENT DEPARTMENT

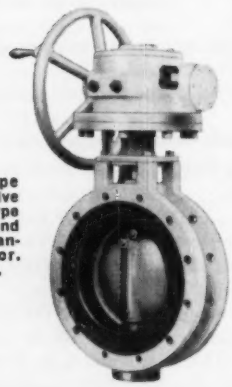
GENERAL ELECTRIC

TIGHT CLOSURE is NO PROBLEM with ROCKWELL BUTTERFLY VALVES



The valve disc seats drop-tight against the resilient seat of the elastomer liner from maximum line pressure to high vacuum. Manual or mechanical valve operation is simple, positive, fast. Streamlined design; low pressure drop; no fouling or jamming with foreign matter.

Wafer type butterfly valve with spool type rubber liner, available in "Keelok" snap-in, easily replaceable type or vulcanized to body. Shown with pneumatic operator. Bulletin 583.



Flanged type butterfly valve with spool type rubber liner and worm gear manual operator. Bulletin 582.

W. S. ROCKWELL CO.

2420 ELIOT ST., FAIRFIELD, CONN.

New Equipment . . .

chromatography, is described in a four-page bulletin.

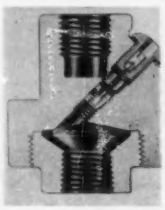
The literature features a new gas chromatograph that is believed to be considerably more accurate than conventional mechanical cam timers. In addition, the unit has a higher degree of stability in column temperature, and permits either bar graph, spectrum, or manual chromatographic presentation. Photographs and diagrams are used to illustrate the controller, contained in a locked dust-proof housing, and the analyzer, in an explosion-proof housing. Mine Safety Appliances Co.

Circle E11 green card, last page

Diaphragm Protects Gage From Corrosive Chemicals

Two newly-designed pressure gage accessories, a "pulsation dampener" and a "chemical attachment" offer improved performance and easier maintenance where gages must be protected from the damaging effects of pulsating pressures or corrosive chemicals.

Both accessories have a diaphragm (stainless steel or Neoprene) which separates the measured fluid from the gage measuring element. Space above the diaphragm is filled with a viscous, non-freezing liquid which transmits the measured pressure to the gage element. For pulsation dampening, there is an adjustable restriction in a passage from the diaphragm top to the gage. A unique feature of the design is that it permits access to this passage at the side of the unit. It is not necessary to unscrew the gage to fill the top chamber or perform routine maintenance.



The pulsation dampener has a threaded plug, externally adjustable with a socket-head wrench. A tapered slot in the side of this plug varies the opening of the passage to the gage. This regulates the degree of dampening for all conditions of flow, viscosity, and rate of pressure pulsation. Gages equipped with the dampener can be used with fluid temperatures between (50 and 100° F) without temperature correction. When used at temperatures outside of these limits, the gage will be accurate only at the temperature at which it is calibrated. United States Gauge Div., American Machine & Metals, Inc.

Circle E12 green card, last page

When to Use Pressure Temperature Controllers

A new six-page catalog describes the pneumatic pressure and temperature

Both a

PROGRAMMER

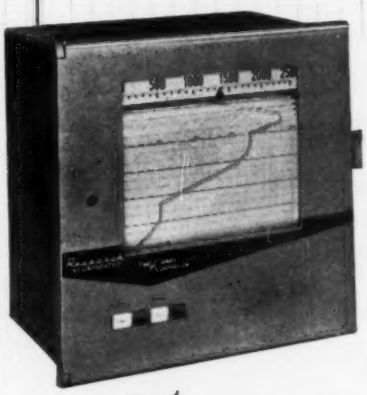
guided by a pencil-drawn curve

NO CAMS

and a

RECORDING CONTROLLER

which superimposes a record of actual process performance and applies corrective control when performance deviates from the plotted program

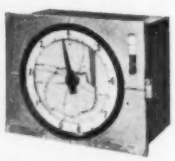


PREKORDER TRADE-MARK

brings new flexibility to the automation of industrial process with closed-loop control.

1. **Pencil Programming** — No cams to cut.
2. **Superimposed Recording** — PreKorder's permanent record of process performance on a program chart overlay permits continuous visual comparison of record and chart.
3. **Programmed Limits**—To trigger alarm or shut-down circuits in case of process malfunction, just pencil allowable operating limits on the recording chart.
4. **Programmed Gain**—Varying the space between pencilled program lines varies the proportional control band or system gain.

Typical PreKorder applications are in programming temperature, pressure, power, load, flow, position, and other process variables. Both round and strip-chart models are available.



RI RESEARCH INCORPORATED

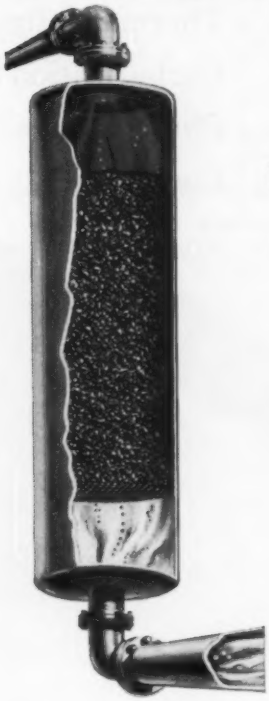
ADSORPTION KNOW-HOW!

REFINING

ODOR REMOVAL

SOLVENT RECOVERY

GAS PURIFICATION



DECOLORIZATION

WASTE PURIFICATION

CATALYSIS

WATER PURIFICATION

PITTSBURGH'S got it . . . and it's available to you!

IF YOU have an adsorption problem, call for the services of a Pittsburgh Technical Representative. He has an extensive store of practical adsorption "know-how" which may be of real value to you.

He'll be able to evaluate and advise on improvements in your present system . . . or help your people set up a small-scale laboratory column to demonstrate the dramatic adsorption efficiency of Pittsburgh Granular Activated Carbons.

Pittsburgh developed coal-derived granular carbons and produces them today in a wide range of types to rigid, printed specifications. Because of their controlled pore structure and outstanding adsorption qualities, Pittsburgh Granular Activated Carbons are setting a new standard of adsorption efficiency and economy in a constantly growing number of continuous column systems throughout industry.

Call or write us the details of your adsorption problem . . . *today!*

Want More Information? Send for this Booklet

There's a type of Pittsburgh Granular Carbon ideally suited to solve your particular adsorption problem. Write for folder describing Pittsburgh Activated Carbons in both liquid and vapor phase applications . . . it's free.

ACTIVATED CARBON DIVISION

PITTSBURGH CHEMICAL CO.

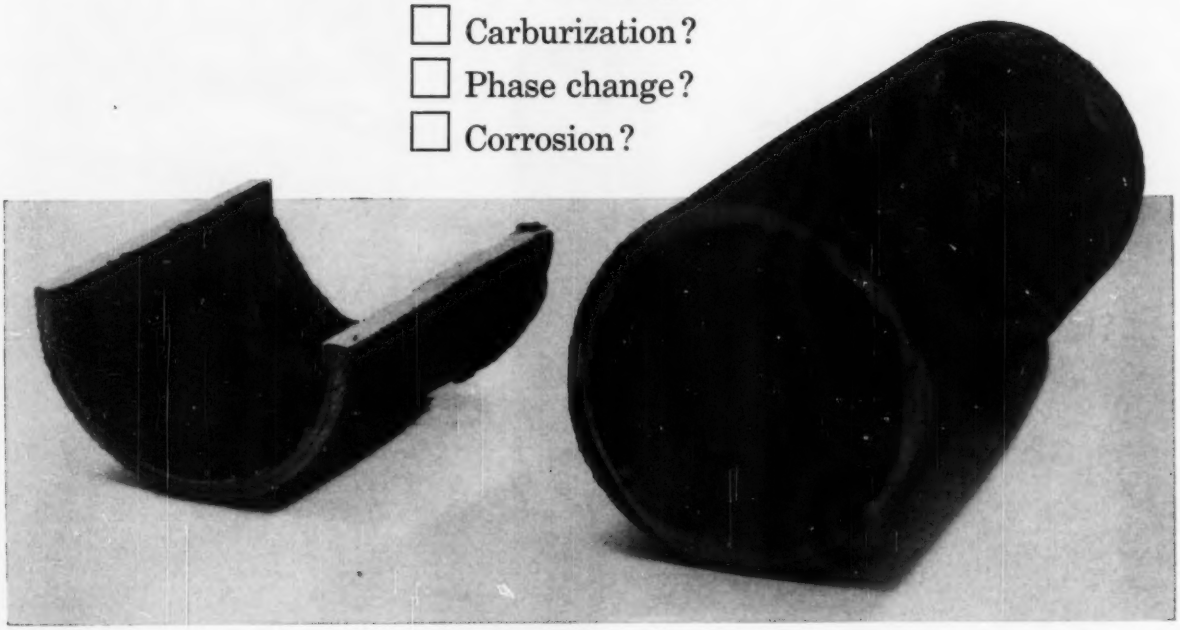
GRANT BUILDING PITTSBURGH 19, PA.

A Subsidiary of PITTSBURGH COKE & CHEMICAL COMPANY

1207

Which was the Failure Mechanism here?

- ☐ Creep?
- ☐ Oxidation?
- ☐ Thermal fatigue?
- ☐ Carburization?
- ☐ Phase change?
- ☐ Corrosion?



The selection of materials and the design of castings for high-temperature service (1200-2300° F) in refineries and chemical plants have been dictated by concentration on corrosion problems. True, corrosion problems are accelerated by the application of heat.

But corrosion did not produce the failure shown above. This failure is the result of carburization. And carburization is one of *five primary* causes of high-temperature equipment failure: creep, oxidation, thermal fatigue, carburization and phase change.

To insure longer service life from his high-temperature equipment, the corrosion engineer must concern himself with an analysis of these mechanisms as related to his specific operating conditions.

In terms of refinery and chemical plant operations, the causes and failure forms of these mechanisms are as follows:

Creep failures are caused by temperature and stress and are speeded up by temperature cycles in the operations. Creep failures manifest themselves as dimensional distortions.

Oxidation is produced by the atmosphere used in the operation and the temperature. Scaling is a characteristic of this failure.

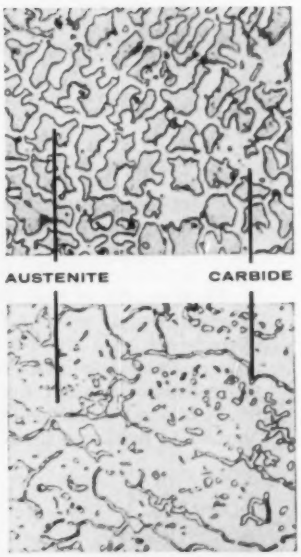
Thermal Fatigue arises from cyclical heating and cooling and thermal gradients across the metal section. The failure evidences itself as cracking and distortion.

Carburization, the absorption of carbon by the metal, occurs at high temperatures in carbonaceous atmospheres. The composition change produces lower hot strength.

Phase Changes, such as sigma formation, impair the properties of the material. Phase changes are evidenced by brittleness at room temperatures.

The mechanisms are interrelated and may jointly cause failure of the equipment. However, certain operating conditions at high temperatures lead to failures by one mechanism or another.

Subsequent advertisements in this series will treat each of these mechanisms in more detail and illustrate what Electro-Alloys is doing to minimize their effects.



Photomicrograph (250x) contrasts inside (top) and outside diameters of material after carburization failure.

AMERICAN Brake Shoe COMPANY **ELECTRO-ALLOYS DIVISION • Elyria, Ohio**

"GREAT CARE MUST BE TAKEN IN SELECTING A GASOLINE ADDITIVE"

FMC offers Dependability, Manufacturing skill, Choice of products for Gasoline Additives

Dependability – FMC protects the refiner by producing ignition control additives from basic raw materials...assuring you of optimum quality control throughout the production process, and providing you with a dependable source of supply for these products.

Manufacturing skill–FMC has a reputation for technical know-how based on more than 25 years of experience in the production of organic phosphorus compounds.

Choice of products – FMC offers you several phosphorus compounds for consideration as combustion deposit modifiers . . . will soon be in a position to supply new compounds, enabling you to choose the additive best suited to your particular conditions.

If you need a phosphorus additive to eliminate engine knock, reduce surface ignition and spark plug fouling, you can rely on the experience and facilities of FMC. Write for more information about FMC gasoline additives. We will be glad to show how these products can meet your most exacting specifications.

Putting Ideas to Work

FOOD MACHINERY AND CHEMICAL CORPORATION

●Chemicals & Plastics Division

Sales Dept., 161 East 42nd Street, New York 17, N.Y.

New Equipment . . .

controllers which control pressures up to 10,000 psi, and temperatures from —125° to 1,000° F. They are simple, self-contained and give precise response (1 percent middle half of scale). Corrosion resistant materials are used throughout.

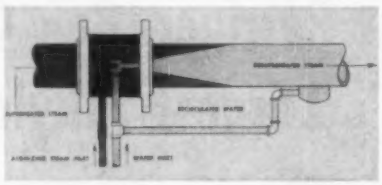
The catalog describes features and accessories, and gives dimensions, specifications, materials of construction and complete engineering information. "When to use a Controller" is also explained. OPW-Jordan Corp.

Circle E13 green card, last page

Desuperheaters Work Well At 50-1 Turn-Down Ratios

An entirely new line of steam ejector, atomizing-type desuperheaters perform dependably with turn-down ratios as high as 50 to 1, in ranges of 10 to 50° F above saturation temperature, provided they are equipped with adequate pressure and temperature controls. The only other limitation regards the atomizing steam pressure which must be at least 1½ times desuperheater steam pressure and 2 percent of total flow.

The new Fig. 6970 desuperheater also features straight-through-flow design and are manufactured for installation directly



in the superheated steam line with welded, flange or nozzle connections.

Research engineers discovered that even finely-atomized water "falls out" of the stream of steam, without being vaporized, at low pipe velocities. This "fall-out" causes an erroneous reading on the part of the temperature sensing device and the temperature controller responds by causing excess water to be pumped into the desuperheater.

These desuperheaters correct this condition by collecting the unvaporized cooling water from the steam pipe line and recirculating it to the atomizer. At normal flow rates, when there is no excess water collected in the line, the unit operates in the conventional steam-atomizing manner. Schutte and Koerting Co.

Circle E14 green card, last page

Selecting the Right Type Mechanical Seal Is Vital

To obtain satisfactory performance, long, trouble-free life with a minimum of maintenance, the selection of the proper type of mechanical seal on pumps used in the petroleum refining and petrochemical industries is of vital importance.

5,000 P. S. I. MERCOID PRESSURE CONTROL

OPERATING RANGE
500 to 5,000 psi.

TYPES AVAILABLE

DXA-21
minimum differential 450 psi.
DXA-521
minimum differential 200 psi.
DXS-221
minimum differential 150 psi.

EXTERNAL ADJUSTMENTS

SEALED MERCURY CONTACT

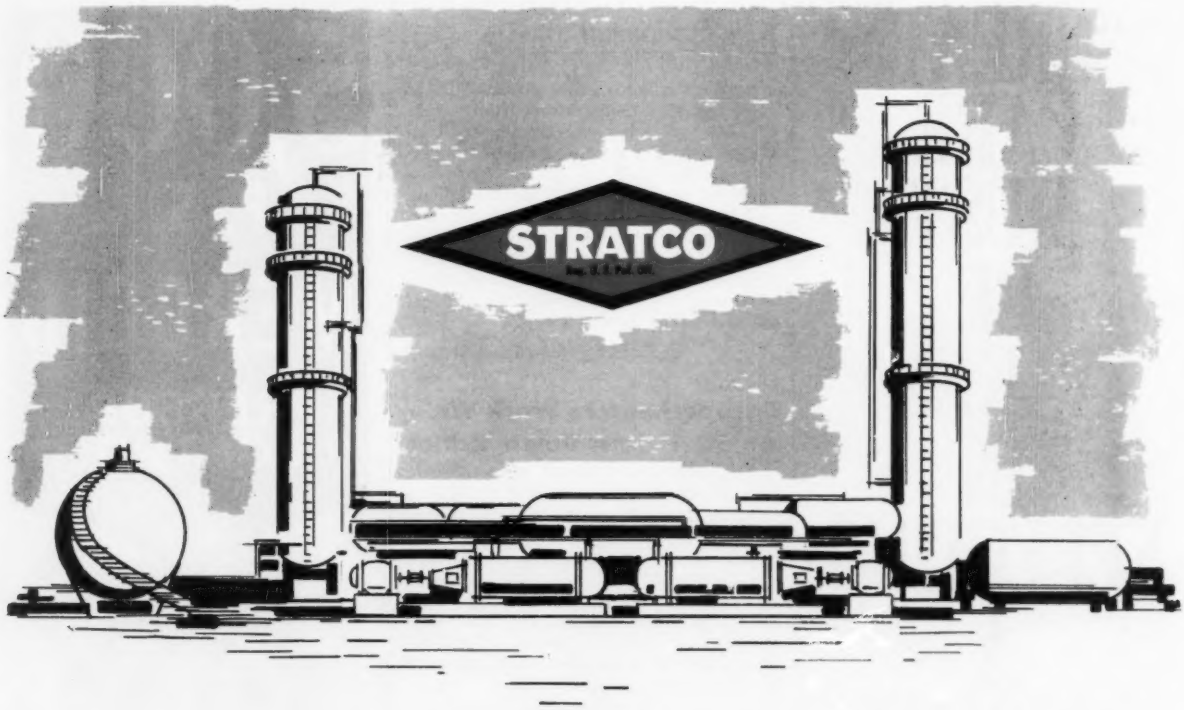
VISIBLE ON-OFF CIRCUIT

VISIBLE CALIBRATED DIAL

Available in three case styles;
General Purpose
Weather-Proof
Explosion-Proof

WRITE FOR BULLETIN O-21

THE MERCOID CORPORATION
4201 Belmont Ave., Chicago 41, Ill.



Effluent Refrigeration Chosen for World's Largest Alkylation Unit

At its Texas City, Texas plant, American Oil Company has contracted for the installation of the largest single alkylation unit in the world. The plant will use the Stratco system of effluent refrigerated alkylation to process a mixture of propylene and butylene olefins. Design capacity is approximately 15,000 barrels of crude alkylate per day. The total alkylate will be used as a high octane blending component in motor fuel, without debutanizing or rerunning.

Stratco's extensive alkylation experience in the design of this type plant is available to refiners without charge. Through the use of electronic computation various design cases can be quickly screened and optimum arrangements can be developed.

Specific inquiries are cordially invited.

STRATFORD ENGINEERING CORPORATION • PETROLEUM REFINING ENGINEERS

612 West 47th St. Kansas City 12, Mo.

REPRESENTATIVES

D. D. Foster Co., Pittsburgh, Pa.
D. D. Foster Co., S. Charleston, W. Va.
Lester Oberholtz, Los Angeles
Rawson-Houlihan Co., Inc., Houston
Rawson-Houlihan Co., Inc., Beaumont, Texas
The Rawson Co., Inc., Baton Rouge
F. J. McConnell Co., New York

C1160

New Equipment . . .

The physical and chemical compositions of the liquids to be handled, the temperatures and pressures involved are factors which must be given careful consideration if optimum mechanical seal service is to be obtained.

A 16-page data booklet on mechanical seal selection describes the various types of seals available and their application under various conditions of service. The use of seals on high temperature services to 650° F is fully covered with cooling rates and methods explained. Specific recommendations of the seal manufacturers are given. Numerous sketches and detailed drawings serve to amplify the text material. Goulds Pumps, Inc.

Circle E15 green card, last page

Heating Oil Additives Cost 75¢ Per Pound

Two new additives are designed to depress the pour points of heating oils.

Paradyne HO-10 and HO-20 "promise important savings to refiners and marketers of heating oils that are destined for cold weather service," the company said.

For the refiner, the additives offer greater freedom in adjusting operations and inventories to meet changes in demand. They also make possible the maximum use of high-pour stocks in heating oils by releasing low-pour stocks for use in other fuels.

The new additives were tested extensively during severe cold weather in Northern Ontario, Canada, and in Northern Maine. These field tests demonstrated the two additives improve the low-temperature properties of both moderately and highly pour-depressed heating oils.

Concentrations of 0.01 to 0.1 weight percent can lower the pour points of heating oils by 10 to more than 70°F.

Both additives are liquid at room temperatures and can be handled like fuel oil. They are compatible with other additives commonly used in finished heating oils, the company said.

Paradyne HO-10 and Paradyne HO-20 are available in commercial quantities at 75 cents a pound. Enjay Chemical Co.

Circle E16 green card, last page

316-Page Lab Glassware Catalog Lists 12,000 Items

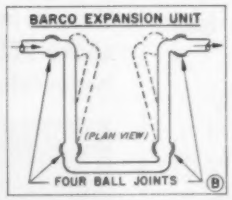
Detailed product information on 9,000 laboratory apparatus items is given in a new Pyrex brand laboratory glassware catalog. The 316-page, color-coded book is designed for quick and easy reference. It contains illustrations of all apparatus and chemical ware.

Some 42 new items are included in the book which replaces the present laboratory glassware catalog and all supplements.

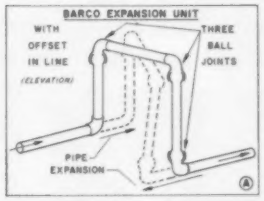
The new volume, designated LG-2,

Handling Pipe Expansion in 1,300 ft. Asphalt Lines

PROBLEM—**At this plant in Arkansas, asphalt at 500°F is pumped from refinery through approximately 1,300 feet of steam traced 6″ insulated steel pipe. Heating of the piping causes a considerable increase in length. The problem of calculating movement and making proper allowance for this pipe expansion was complicated by the fact that the piping runs at various angles and elevations.** ***(See ANSWER below.)***



These schematic diagrams from Barco Bulletin 31A explain the accompanying photos.



BALL JOINT EXPANSION UNITS

(NO REACTIVE FORCES)

ANSWER—Barco Ball Joints solved the "pipe expansion" problem SIMPLY, ECONOMICALLY, EFFECTIVELY. No complicated calculation of stresses was required—Barco Ball Joints (see arrows) provide *points of flexibility*. In offsets (A), three joints allow for expansion; or four joints (B) are used to form a minimum size expansion loop.

Rugged "Fire-Safe" Barco joints have no thin wall sections, no critical points of fatigue, no rubber seals. They develop no "end thrust"... *no reactive forces;* require no expensive anchoring. They are ideal for steam and all kinds of fluids, including asphalt. Choice of styles and sizes ½″ to 16″ to meet your requirements. SEND FOR BARCO BULLETIN 31A.

BARCO MANUFACTURING CO.
542M Hough Street, Barrington, Illinois
In Canada: The Holden Co., Ltd., Montreal

For more data on advertised products, use Readers' Service Cards, last page.

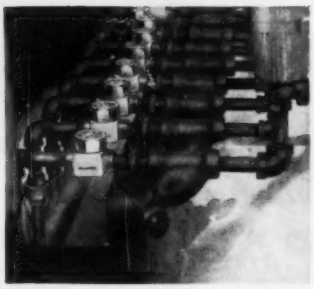
SARCO TOPICS

HOW TO SOLVE COMMON TRACER LINE PROBLEMS

How to cure water hammer with a steam trap that will operate in vertical position

Water hammer is an inherent problem in long tracer lines. So is freezing. Both problems can be overcome, and here's an example of how it has been done. At the Socony Mobil Oil Company's Paulsboro, N. J., refinery, they found that the Sarco Thermo-Dynamic Steam Trap, type TD-50, not only withstands water hammer, but installing the trap in a vertical position —which permits free drainage—presents no problems at all, thanks to its unique thermodynamic principle. In fact, 90% of the 250 TD-50's at this plant are vertically mounted. They never block heat transfer, and they remove condensate and air as fast as they collect.

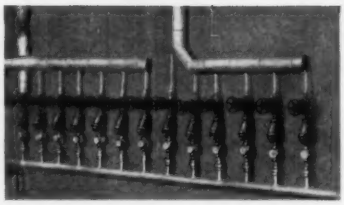
How to handle varied steam pressures — without adjustment



Can a trap — without adjustment — handle steam pressures that vary from 15 to 160 psi? Can the *same* trap vent air and drain condensate as rapidly as it is formed, be easy to install and require practically no maintenance at all? That was the problem set up by the engineering staff of Armour Chemical Division's McCook plant. They solved it by testing many traps. Their conclusion: Sarco TD-50 steam traps meet or beat their specifications, because:
they discharged condensate as fast as it formed, without wasting steam;
their compact inline construction made installation easy, even in tight quarters;
maintenance was practically negligible;
no adjustment was necessary for varying steam pressures. (In fact, the TD-50 is self-adjusting through its full operating range of 10-600 psi.)

No other steam trap can so adequately solve all these problems at one time.

How to be certain process fluid stays above 280° F. when outside temperature drops to —10° F.



The problem of maintaining design temperatures on tracer lines need not be difficult, no matter how extreme the conditions seem to be. For example, the tracer lines in a phthalic anhydride process at Witco Chemical Company's new Chicago plant had to be maintained above 280° F. Below this temperature, the chemical sets and the whole system would have to be taken apart and re-assembled. That's not all; ambient temperatures sometimes could drop to −10° F.

With reliability as a prime consideration, Scientific Design Company, Inc., who designed and constructed this brand new plant, selected the TD-50.

Because the TD-50 can be mounted vertically, freezing was no problem either. Added benefits that matter on tracer lines: the TD-50 is compact, light in weight, easy to install.

What is the most reliable tracer line trapping method to prevent unscheduled shutdown?

Particularly in refineries, steam traps have to function under exactly the kind of conditions that you'd expect to cause failure—they must function equally satisfactorily on low pressure or exhaust steam and on up through high-pressure, high temperature ranges. Not only that, but outside temperature may vary from subzero to subtropical. If maintaining design temperatures in your tracer lines appears to be hampered by these problems, consider how Phillips Petroleum Company, Kansas City, solved them. They found a trap which drains their tracer lines automatically over a full range of pressure, temperatures and loads. It's the Sarco TD-50 Steam Trap.

With only one moving part—a stainless steel disc, the TD-50 has little that can go wrong. In fact, it's so free of trouble that Phillips Petroleum Company consider their TD-50's as reliable and efficient as the piping. They now rely on 1800 of them throughout the plant. 1408

FOR FULL INFORMATION ON TRACER LINE TRAPPING or on any steam trapping problem—see your Sarco Sales Representative or write to

SARCO

SARCO COMPANY, INC.
635 MADISON AVENUE, NEW YORK 22, N. Y.
PLANT: BETHLEHEM, PA.
STEAM TRAPS • TEMPERATURE CONTROLLERS
STRAINERS • HEATING SPECIALTIES

For more data on advertised products, use Readers' Service Cards, last page.

SARCO

Here are 7 Sound Reasons Why the Thermo-Dynamic® Does a Better Job of Trapping

1. *Simplicity*—has only one moving part. 2. *Maintenance*—practically zero. 3. *Wide pressure range*—one trap for all pressures from 10 to 600 psi. 4. *Uniform performance*—operates equally well on heavy, light, or no condensate load. 5. *Operates against back pressures*—up to 50% of inlet pressure. 6. *Rugged*—unaffected by superheat, water hammer, vibration, or corrosive condensate. 7. *Minimizes inventory* of spare parts.

Maintenance Time: 40 Seconds. If it now takes your maintenance crew more than a couple of minutes to service an ordinary trap, you're throwing away valuable time. This Sarco Thermo-Dynamic can be cleaned, blown out if necessary, and reassembled on the line in as little as 40 seconds.

For Prompt Information on the TD-50 . . . or for fast help on the efficient solution of any steam trapping problems, get in touch with a SARCO District Office, Sales Representative, or Distributor. (There's one near you.)

Only SARCO makes all 5 types:
Thermo-Dynamic* • Thermostatic • Liquid Expansion • Float Thermostatic • Inverted Bucket

*U.S. Pat. No. 2,817,353 TM Reg. U.S. Pat. Off. 1409

SARCO
SARCO COMPANY, INC.
635 MADISON AVENUE, NEW YORK 22, N. Y.
PLANT: BETHLEHEM, PA.

New Equipment . . .

contains information on 3,000 standard items and 6,000 custom-made items. The book also covers physical properties of the glasses used for laboratory ware as well as technical information on the use of these glasses.

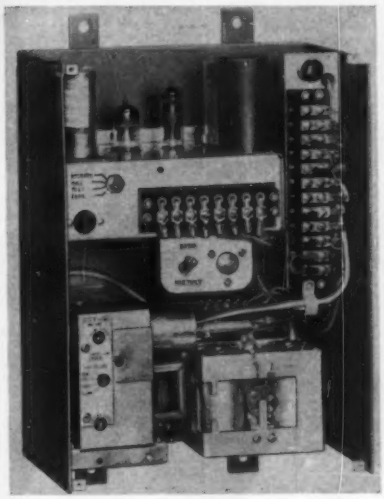
A major revision is the listing of items by product type rather than glass composition or brand name. The editors said this saves time in determining the right product for a specific application and makes the book a more valuable reference volume. Corning Glass Works.

Circle E17 green card, last page

Electronic Instrumentation Possible with New Computer

A new analog computer permits electronic instrumentation to be used for many control functions that formerly required pneumatic systems.

A typical example of how the C4A/2 computer can increase the sophistication of electronic control systems is the company's internal reflux computer. This system measures and controls the internal reflux of a fractionator column by using two computers to solve the following equation:



$$R_i = R_e (C + KT_d)$$

where:

R_i = internal-reflux flow
R_e = external-reflux flow
T_d = temperature difference between external reflux stream and overhead vapor

and: K and C are constants relating to the material and process.

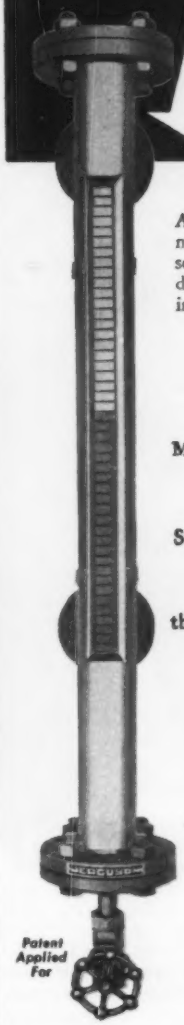
The computer also permits electronic instrumentation to be utilized for a wide variety of other less specialized functions.

Design for back-of-panel mounting, the computer measures 9-5/8 inches x 12-9/16 inches x 6-1/8 inches. Its input

the New Jerguson

MAGNETIC GAGE

for liquid levels



An important advancement in liquid level observation for plants with dangerous explosive or inflammable conditions.

Safety design seals against escaping gases.

Measuring mechanism in stainless steel chamber.

Scale mounted outside chamber; magnetically actuated through chamber wall.

Distinct, accurate level shown in red contrasted with silver above.

Job designed, correlating pressure, temperature, and specific gravity.

Available with electric alarms.

Can also be used for interface indication.

Write now for engineering sheet on Jerguson Magnetic Gages.

JERGUSON
Gages and Valves for the Observation of Liquids and Levels
JERGUSON GAGE & VALVE COMPANY
100 Adams Street, Burlington, Mass.
Offices in Major Cities

For more data on advertised products, use Readers' Service Cards, last page.

Performance makes the world of difference

Fig. 6003—Steel gate valve for 600 W.P. Outside screw rising stem and yoke. Bolted flanged bonnet. Flanged ends.

Fig. 3061A—Steel horizontal swing check valve for 300 W.P. Heavily bolted flanged cap. Full unimpeded flow through when wide open.

Fig. 3058—Carbon steel, screwed end lubricated plug valve. ASA 300 pounds. Screwed gland type, wrench operated.

Fig. 2207G — Semi-steel, flanged end, lubricated plug valve for 200 pounds W.O.G. Bolted gland type. Worm gear operated.

In Powell's complete line of valves are STEEL valves for handling fluids in refineries, petrochemical plants and petroleum storage facilities all over the world.

For 100 years Powell valves have served the vital lifelines of the oil industry. Today, the Powell line includes all types of steel, bronze, iron and corrosion resistant valves in sizes to meet every flow control requirement of the wide-spread petroleum world.

Powell can quickly supply all your valve needs and help solve your valve problems. Contact your nearby Powell distributor. (There's one in all major cities.) Or write directly to the Wm. Powell Company.

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New Equipment . . .

and output signals are within the standard autronic range of 0 to 0.5 volts AC. The unit operates on regular 115-volt power, and is fuse protected. Swartwout Div., Crane Co.

Circle E18 green card, last page

Tank Cleaner Works While Suspended from Hose

A new light-weight, heavy-duty tank cleaner is water-powered, weighs only 42 pounds and can be used with either two or four nozzles. Nozzles rotate in both the horizontal and vertical planes simultaneously, providing a thorough washing pattern inside any tank or vessel.

The unit operates efficiently at pressures from 28 psi to 170 psi and at temperatures up to 203°F. Capacity range is 3,800 to 8,500 gallons per hour. It performs effectively in any position—suspended from the end of a hose or on a special folding stand.

Wearing parts are made from beryllium-bronze, stainless steel and teflon for resistance to acid. The gear case with lubricant is a permanently-sealed unit, making possible permanent "in place" installations. A slip clutch on the nozzles protects against internal damage from shock or accidental dropping. These features make the model "H" tank cleaner virtually maintenance-free. Sellers Injector Corp.

Circle E19 green card, last page

Turbine Meter Outworks Positive Displacement Type

Unique design features of a new 10-inch turbine type meter include a highly sensitive rotor metering element weighing only four pounds, a newly-developed viscosity compensator and a magnetic coupling completely sealed from the line product.

In addition, for what is believed to be the first time in the industry, an operating range chart has been devised which shows flowrate and viscosity conditions under which the 10-inch Turbo-Meter can be used and still retain its extraordinary accuracy and repeatability.

The integral viscosity compensator makes possible sustained accuracy regardless of the viscosity of the product being measured. It maintains accuracy by imposing a mechanical drag on the turbo-rotor directly proportional to the liquid viscosity.

A magnetic drive, sealed from the line fluid and mounted on the downstream end of the turbo-rotor shaft, transmits power to either a mechanically or

PALMER

Mercury Actuated Dial Thermometers now in three types to suit any requirements

PATENTED
FULL 4½" DIAL FACE. Stem can be placed at any angle and case can be rotated to any readable position.
1 RIGID STEM DIAL THERMOMETER tapered bulb, interchangeable with standard industrial thermometer separable socket. (As illustrated above.)
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3 FLUSH MOUNTED DIAL THERMOMETER for panel mounting with flexible connecting armor.
ALL THREE TYPES HAVE A FULL 4½" DIAL FACE.

■ **for accuracy:** Mercury actuated . . . Compensated by Invar. Guaranteed Accurate 1 scale division. ■ **for angularity:** Can be adjusted to most readable position at any angle desired. ■ **for readability:** Bold Black Numbers . . . 11" of scale Reading Dial face can always be placed in easiest readable position. ■ **for interchangeability:** Also specify "PALMER" Separable sockets as they are interchangeable for Dial or Industrial type Thermometers.

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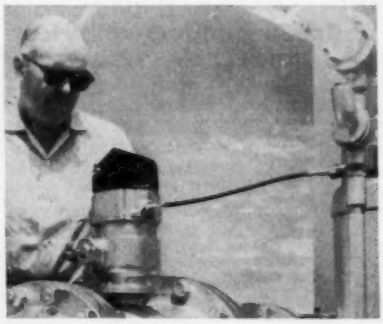
New Equipment . . .

electrically-actuated register.

With accuracy better than plus or minus 0.15 percent, the 10-inch Turbo-Meter will indicate the amount of crude or refined oil products passing through a 10-inch pipe line at rates as high as



7,000 barrels per hour. It has a repeatability of better than one part in 5,000 and head loss lower than that of any positive displacement meter of the same capacity.

Cost of the Turbo-Meter is less than half and weight is less than one-eighth that of positive displacement meters of the same capacity. Rockwell Mfg. Co.

Circle E20 green card, last page

Dry Chemical Feeder Accurate to 1 Percent

The new type "G" chemical feeder is a general purpose feeder because it handles all dry chemicals normally used in water and waste treatment, whether the chemicals are in powder, granule or lump form up to ¾-inch in diameter.

Its finely-balanced weighing mechanism gives an accuracy of plus or minus

1 percent of the set rate over an operating range of 20:1.

The entire "G" feeder is housed in a dust-tight enclosure. All electrical and operating controls are integral parts of the unit, but are separated from the feeding mechanism by a dust-tight partition. Agitators within the hopper prevent "arching" or "hold-up" of chemicals. Infilco, Inc.

Circle E21 green card, last page

Antioxidant for Lube Oil Protects Against Cam Wear

Ethyl Antioxidant—ZDP, added to lubricating oil, acts as an antioxidant and a mild extreme-pressure additive, thus

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SERV-RITE drilled protecting wells are made in types, lengths, and of alloys to meet any temperature and pressure condition in vessels and flow lines.

Every well is carefully made to assure a plus service. Selected bar stock is machined to within accurate limits. Bore concentricity is held within 5% of wall thickness, depending on well length. They are tested to withstand pressures up to 3000 psi., depending on the wall thickness. Exterior surface has a mirror-like finish for minimum resistance to flow in lines.

Complete assemblies can also be furnished with suitable thermocouple, head, flange, fittings, etc.

Give SERV-RITE a trial on your next drilled well requirements. There is none better.

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for specifications, size, and ordering information on SERV-RITE drilled wells.

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D. I. S. STRIPS 10-INCH SCALE FROM 12-INCH PIPELINE IN JUST ONE DAY!

Dense scale deposits of oxides, sulfides and sulphur—10 inches thick in some places—clogged a 12-inch fuel supply line. Dow Industrial Service engineers stripped every trace of deposits from this 750-foot pipeline—restoring full capacity—in *just 24 hours!*

Solvents and a pipeline pig did the job. But for different conditions, D. I. S. uses other techniques to get the same result. For example, when scale blocked a 24-inch, quarter-mile-long waste line, D. I. S. engineers knocked out the deposits with a special D. I. S.-designed jet mole. Though this underground pipeline was buried 10 feet deep, D. I. S. cleaned it completely in only 16 hours!

Nation-wide Dow Industrial Service first analyzes the job to be done, then selects the technique which will do the best job, fastest. D.I.S. cleans all kinds of lines—fresh water, boiler feed-water, gas, waste and other lines—and every kind of process and heat exchange equipment.

In addition, D. I. S. offers complete consulting laboratory service for water treatment and waste processing problems, backed by the technical resources of The Dow Chemical Company. For cleaning *any kind* of equipment, *anywhere* in the U. S., write or call DOW INDUSTRIAL SERVICE, 20575 Center Ridge Road, Cleveland 16, Ohio.

DOW

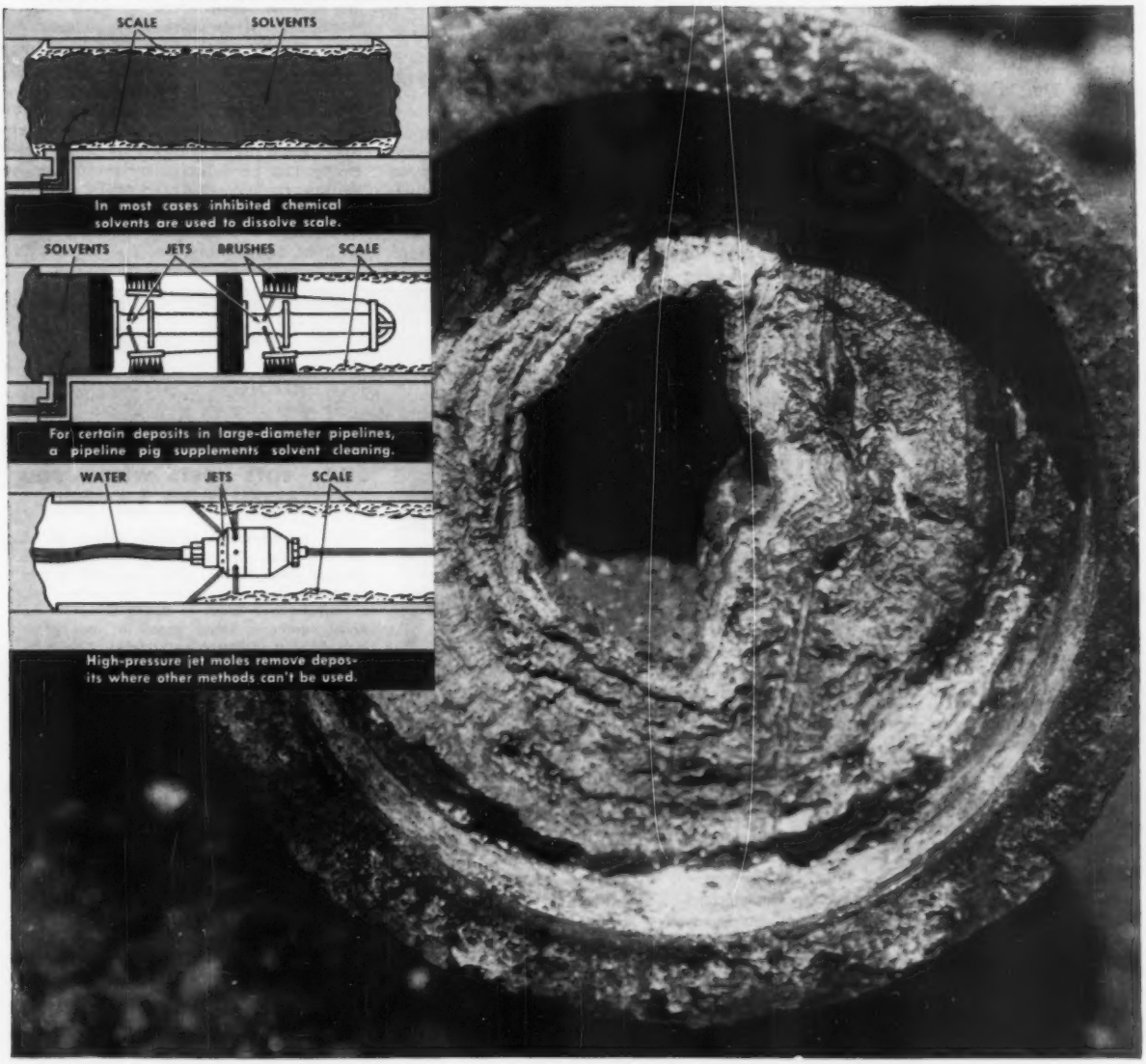
DOW INDUSTRIAL SERVICE • Division of The Dow Chemical Company

From these three methods, D. I. S. selects the one best suited to your specific pipe-cleaning problem.

In most cases inhibited chemical solvents are used to dissolve scale.

For certain deposits in large-diameter pipelines, a pipeline pig supplements solvent cleaning.

High-pressure jet moles remove deposits where other methods can't be used.



For more data on advertised products, use Readers' Service Cards, last page.

protecting engines against cam and lifter wear. Ethyl Metal Deactivator, which is a chelating agent, is added to gasoline, jet fuels and distillates to counteract the harmful effects of copper on fuels. By chemically combining with the copper particles, the metal deactivator nullifies their tendency to promote oxidation of the fuel.

Both the antioxidant and the metal deactivator will be sold as separate additives. However, the metal deactivator will also be sold in combination with Ethyl Antioxidant 733 as a combination additive for gasolines and jet fuels. Ethyl Corp.

Circle E22 green card, last page

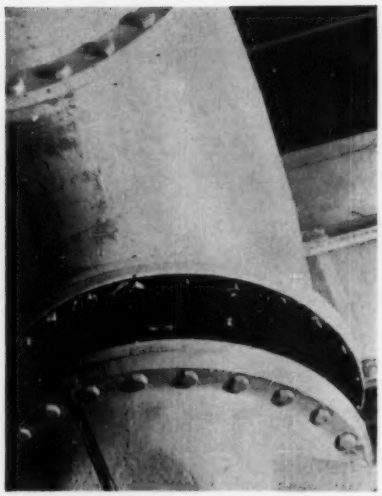
Rubber Expansion Joints For High, Low Pressures

Multi-purpose rubber expansion joints produced by a Dutch firm are available in low and high-pressure units.

For pressure lines, the expansion joints are available in diameters of up to 80 inches. For working pressures of up to 25 atm, at which the bursting strength is over 80 atm, the maximum diameter is 4 inches.

The lengths are: approximately 6 inches for small diameters up to 6 inches; about 10 inches at a diameter of 6 inches to 20 inches; about 12 inches; at diameters of 20 inches to 36 inches; and 16 inches for larger sizes.

The expansion joints are usually de-



signed with a curve with a normal depth of 1½ - 2 inches at a width of 4¾ - 6 inches. They are available with a circular or semi-circular diameter and also with flanges facing inward. Vredestein International.

Circle E23 green card, last page

PVC Pipe, Fittings Catalog Off Press

A 60-page technical data catalog on the rigid unplasticized polyvinyl chloride and fittings has been published. In addition to giving the usual catalog data and illustrations of typical applications in the refining and petrochemical industries, the booklet has some 30 pages of technical data. Included are tables of physical properties, chart of tensile strength vs. temperatures, chart of thermal expansion and contraction, hydraulic data, information on internal pressures and flow rates, friction loss and water flow charts, diagrams for determining maximum working pressures and detailed illustrations and information on installation including cutting, threading, assembly, welding, bending, underground installation and additional technical data. The back of the book includes six pages of glossary terms and definitions applicable to plastics and plastic pipe. Glamorgan Pipe & Foundry Co.

Circle E24 green card, last page

Flow Meter Constructed To Simplify Maintenance

A pneumatic transmitting bellows flow meter, described as having unusual temperature stability, has been introduced for economically and accurately measuring flow or liquid level.

Because of its zero thermo-elastic coefficient, the rebalancing capsule reduces zero and span shifts to less than 0.5 percent per 50°F ambient change.

Modular units, according to the company, simplify operation and maintenance. Each major component of the transmitter can be independently removed by sliding the concentric scale indicator free from the fluorescent-tipped pointer. Span, zero and linearity can be adjusted without disassembly.

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CHANGES THAT DANGER ZONE TO A SAFETY ZONE

. . . cuts costs when you SIMPLIFY PIPE LAYOUT

When you modernize to make money, go all the way. Cut piping costs to minimum with planned simplification. Give your staff a free hand to effect economics—at the same time, convert Danger Zones to Safety Zones. Equip every overhead valve wheel in your plant with Babbitt Adjustable Sprocket Rims with Chain Guides.

- They simplify pipe layout.
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- They are packed completely assembled (one to a carton), with easy-to-follow instructions.
- A hot-galvanized rust proof chain is available for all sizes.

Babbitt Adjustable Sprocket Rims with Chain Guide are carried in stock by most mill supply houses. Just phone your mill supply salesman, or contact us direct.

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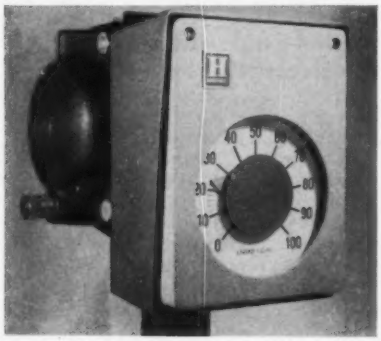
6 BABBITT SQUARE, NEW BEDFORD, MASS., U.S.A.

New Equipment . . .

The newly-designed transmitter provides two-way overload protection while the flow meter itself can take full static pressure overload in either direction.

Rotation of the concentric scale indicator, which is 5 inches in diameter with a calibrated length of 8.5 inches, is on a



270° arc. The weatherproof case, 9 inches high by 7 inches wide by 4 inches deep, is die-cast aluminum with a cover of reinforced fiberglas.

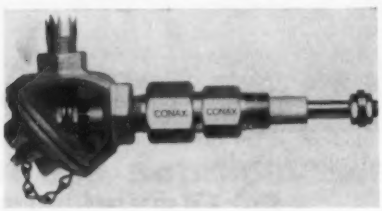
The bellows-type differential pressure meter is available in models for measuring liquid level in closed tanks under pressure or vacuum and for flow or open tank measurements. Brown Instrument Div., Minneapolis-Honeywell Regulator Co.

Circle E25 green card, last page

Gland Pressure Seals Electrical Leads in System

New, electrode glands pressure seal electrical leads into systems operating from .005 microns absolute to 2,500 psi at temperatures from —300° F to +1,850° F. Amperage range is from 3.0 to 200 amps. Recommended 2,000 rms voltage rating provides an adequate margin of safety.

These compact glands, machined from type 303 stainless steel, can be factory



assembled with either stainless steel or copper electrodes in diameters from 3/32-inch to 1/2-inch. Mounting threads range from 1/8-inch to 3/4-inch ips.

They provide high dielectric strength and are especially recommended for highly corrosive applications. Conax Corp.

Circle E26 green card, last page

Pocket-Size Manual Available to Pipe Fitters

Information expected to be at the finger tips of modern pipe fitters and pipe welders is concentrated into a comprehensive 72-page pipe fitters manual.

Text, tables and illustrations in the pocket-size field manual give important mathematical, physical, chemical and metallurgical data and related design, layout and mechanical information at a glance.

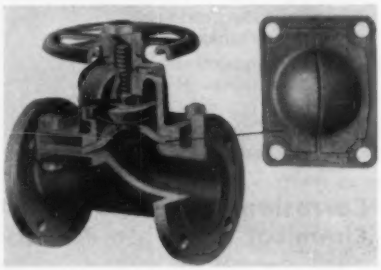
Subjects covered include characteristics of welded and threaded piping; basic mathematical formulas and conversion factors; dimensions of welding fittings and flanges and commercial pipe sizes; electrode data and practical tips on welding and properties of pipe, metals and fluids. Illustrations show methods of pipe alignment, types of pipe hangers and commonly used drafting symbols for arc and gas welding and for pipe fittings. Tube Turns Div., Chemetron Corp.

Circle E27 green card, last page

Teflon-Faced Diaphragms For 4 and 6-Inch Valves

One-piece, reinforced elastomeric diaphragms with a permanently-bonded Teflon face are available for 4-inch and 6-inch diaphragm valves. This type of diaphragm previously was available for 1/2-inch through 3-inch valve sizes.

Chemical resistance and wear life of Teflon-faced diaphragms are said to be equivalent to that of solid Teflon diaphragms, but the price is 25 to 50 percent lower, depending upon size. Additionally, the resilience of the elastomeric



backing of the Teflon-faced diaphragms is claimed to insure tight seating even against solid particles in the line and to provide capacity to absorb considerable shock without rupture.

Teflon-faced diaphragms may be used at service temperatures of —10° F to 240° F continuously, and for short periods of time in temperature ranges up 280° F. Pressures allowable are consistent with the valve rating, normally 150 psi. Typical fluids that can be handled include sulphuric acid, concentrated nitric acid, concentrated hydrochloric acid, organic solvents, chlorinated hydrocarbons, ethers, esters, ketones, and others. Hills-McCanna Co.

Circle E28 green card, last page

Drawings of Vertical Volatile Liquid Pumps

A new three-color, six-page bulletin entitled "Layne Volatile Liquid Pumps" includes cross-section drawings of the standard, short-coupled, vertical turbine pump and the canned-type, vertical turbine pump with uses and applications illustrated. Layne & Bowler, Inc.

Circle E29 green card, last page

REFRACTORY HAYDITE

Makes Higher Heat Resistant Concrete

Haydite aggregate used with Lumnite cement produces refractory concrete suitable for sustained temperatures up to 1800-2000° F., which makes it excellent for tubular heaters, ducts, flues, stacks and catalytic crackers. Weighing from 30 to 40 per cent less than ordinary aggregate concrete, Haydite is exceedingly strong. It has excellent insulating properties and withstands pressures of up to 1130 pounds per square inch. Write today for free folder and complete information about Carter-Waters Refractory Haydite.
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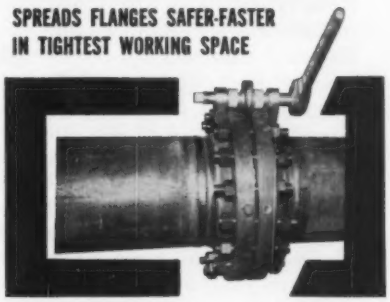
SPREADS FLANGES SAFER-FASTER IN TIGHTEST WORKING SPACE



- Eliminates plant safety hazards and costly down time.
- Spreads all Series pipe flanges. Spreads ring joint flanges.
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DALPAC® 4 SAVES YOU MORE

Refinery customers have found that, in comparison with other inhibitors, Dalpac 4 (Hercules 2,6-di-tert-butyl-p-cresol) saves up to three dollars on every thousand barrels of gasoline produced. Dalpac 4 inhibits gum formation, stabilizes gasoline color, and helps maintain engine cleanliness. Refiners have also found it to be excellent in turbine and transformer oils where it prevents deterioration, and does not affect electrical properties.

For additional information write:

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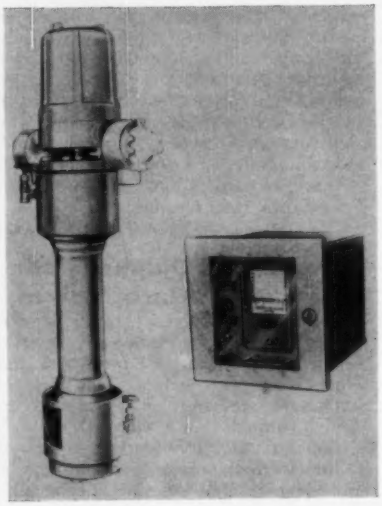
Naval Stores Department
HERCULES POWDER COMPANY
900 Market Street
Wilmington 99, Delaware

NO59-5R

New Equipment . . .

Monitor Checks on Water In Crude from Treater

A new sensor measures the dielectric constant of crude oil as it comes from the separators or treaters. The transmitter instrument sends an electric signal to the diverting controller. When water is present in the crude, the signal to the diverter instrument will be increased. If



this signal exceeds the present specifications of the diverter, the instrument will actuate a switch so that a diverting valve can reroute the crude back to the treater or to storage tanks.

The monitor consists of a Type 4450 sensor and transmitter assembly, and a Type 705 or 706 diverter controller. Fisher Governor Co.

Circle E30 green card, last page

Corrosion Data Charts List Chemical Effect on Metals

The corrosive effects of almost 400 different materials on 16 types of metals are shown in the company's revised corrosion Data Charts.

The charts indicate the corrosion resistance of the metals to various concentrations of more than 250 chemical salts and acids.

The charts were prepared in cooperation with research laboratories of the nation's largest metal producing companies. Nooter Corp.

Circle E31 green card, last page

High-Pressure Gaskets Conform to ASA Standards

A new high-pressure series of standard ASA flange gaskets called the 6400 Series Gask-O-Seal can be used with most all types of ASA flanges—raised-face, flat face, lapped-joint, welding neck, slip-on screwed joints, fitting flanges and others.

The new designs feature safe blow-out proof, metal-to-metal seals, plus reuseability and ease of installation. They eliminate the need for scraping, cleaning or refacing flange faces when repairs to lines or equipment is required.

The gaskets are recommended for temperatures from —65° to +275° F. Special sizes and shapes are also available for higher and lower temperature usage. Parker Seal Co.

Circle E32 green card, last page

Data Book on Packing, Gaskets Published

A new 40-page data book contains comprehensive catalog information on various types of packings and gaskets.

The booklet features reference information showing the effect of gases and liquids on various types of packings and gaskets, the factors which should be considered in selection of a packing and general information such as the eight basic steps to be checked in packing a stuffing box. George Angus & Co. Ltd.

Circle E33 green card, last page

Multi-Stage Centrifugal Pump Handles Many Liquids

A new line of multi-stage, opposed-impeller, centrifugal pumps Type JTC handle hot or cold water, hydrocarbons, chemicals, acids, condensates, and similar liquids. They can also be adapted for medium-pressure boiler feed service and, with minor modifications, they become efficient hydraulic driving devices. Pacific Pumps, Inc.

Circle E34 green card, last page

Eight-Inch Ball Valve Has Fail-Safe Design

An 8-inch, high-capacity, fail-safe industrial Flo-Ball valve with a spring return is top loading for easy access to the internal assembly without removal from the line. It has a top and bottom-guided ball and a floating seat. It also has the characteristics of zero leakage and low-torque quarter-return actuation. Rated at 150 pounds ASA, it is equipped with a close-coupled, compact, air-operated actuator with a manual override. Designated Model 731 V, it can be ordered normally open or normally closed. Materials of construction are either carbon or stainless steel. Hydromatics, Inc.

Circle E35 green card, last page

60-Page Packing Catalog Includes Performance Data

A new 60-page packing catalog and application data book presents specific recommendation and performance data on all types of processing operation packings with special emphasis on corrosion resisting conditions. Crane Packings, Ltd.

Circle E36 green card, last page

R. & G. Schmöle Metallwerke

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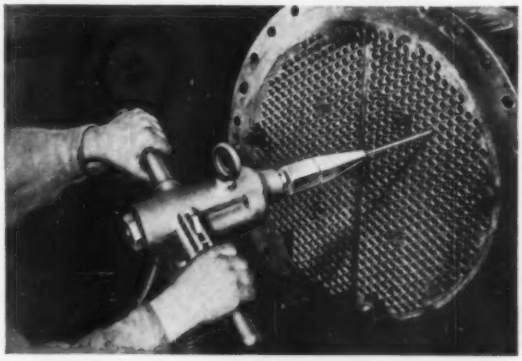
KNOCK OUT SCALE WITH SUPER-POWERED WILSON TUBE CLEANERS

Are your heat exchanger tubes completely fouled with scale buildup? Or, are you looking for that last vital inch of heat transfer efficiency? In either case, efficient, hard-working Wilson Tube Cleaners are the answer.



For heavy duty service, for example, use Wilson air driven Model TP 301 shown above. This super-powerful, 15 lb, light weight, scavenger-type tube cleaner drills and simultaneously flushes out deposits. It is suitable for vertical or horizontal use in straight tubes 3/8" ID to 2 7/8" ID and up to 40' long. Cleans rapidly and thoroughly, operating at high speed at 90 psi. Can run on pressure as low as 50 psi. Other Wilson Cleaners are available for every tube size.

WILSON SUPER-DUTY CARBIDE BITS

TYPE M BIT
An inserted two-lip Helix type for general use. 1½" to 1 19/32" bit OD.

TYPE K BIT
A two-lip Helix type with adaptor for general use. 1¼" to 2¾" bit OD.

TUBE EXPANDERS— Wilson Models 41 and 44 Self-Feeding Tube Expanders are modern tube expanders for the *precision rolling* of condenser and heat exchanger tubes into heavy tube sheets. Ball Bearing Collar Type ½" OD to 2½" OD • **Write for your free copy of Wilson Catalog 77-88. It's a mine of information on tube cleaning and tube expanding problems.**

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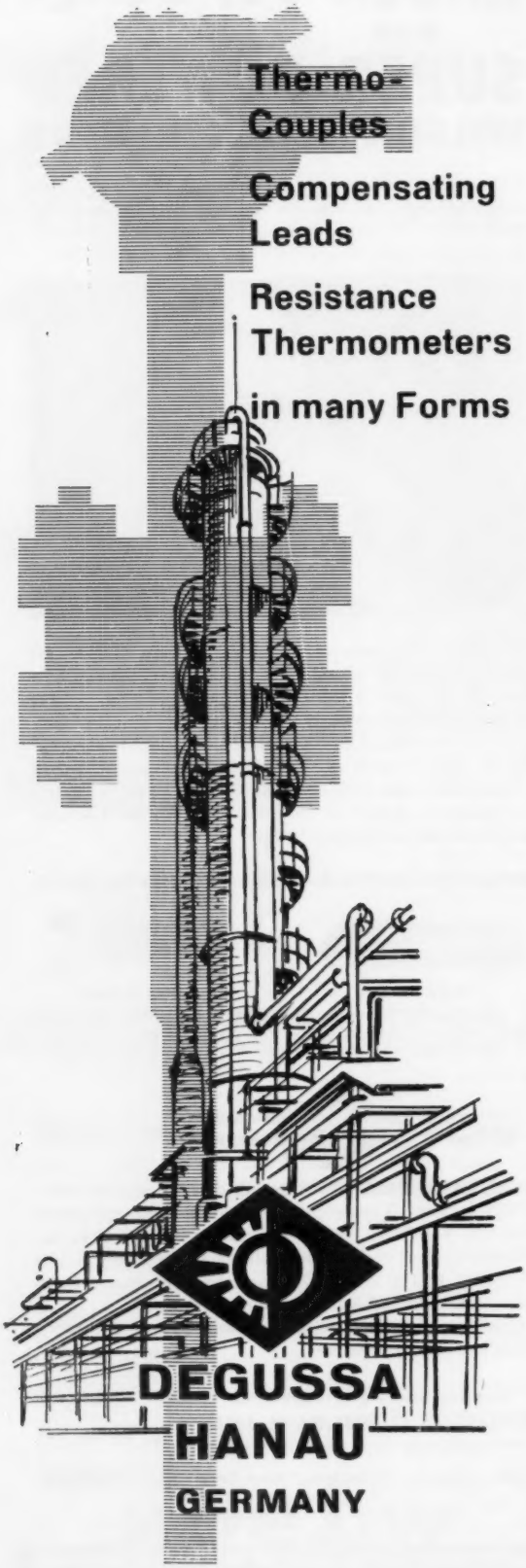

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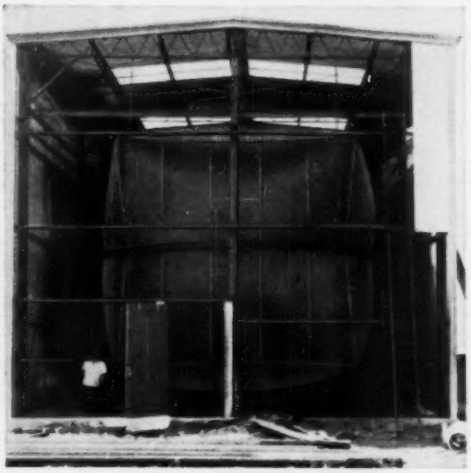

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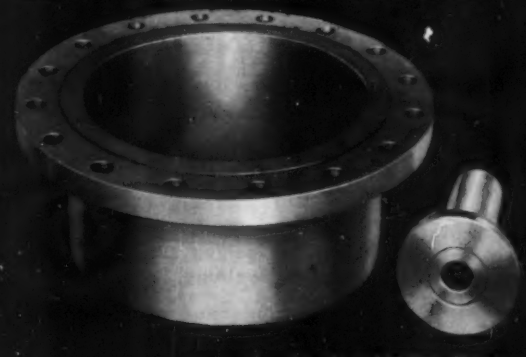

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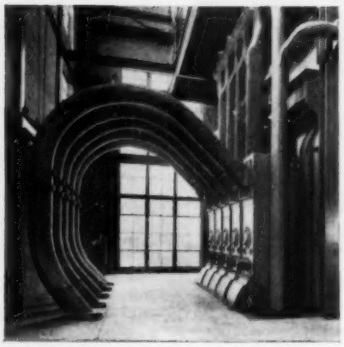

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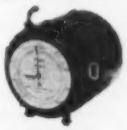

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415b	417	418	419a	419b	420	421a	421b	422a	422b	423	424a	424b	425a	425b	425c	426	427a	427b	428a
428b	429a	429b	430	431a	431b	432a	432b	435	436										

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34Nb	34P	34Qa	34Qb	34R—34S	34T	34U	34V	34Wa	34Wb	35—36—37—38			39	40	41	42—43			
44—45	46	47	48	49	50—51	52—53	54	55	56	57	58—59	60	61	62	63				
64—65	66—67	68	69	70	71—72	73	74	75j	76	77	78—79	80	81	82	83				
84—85	86	87	88—89	90	91	92—93	94	95	96	97	98—99	100—101	102—103						
104	105—106—107—108	109	110	111	112	113	114	115	116	117	119	120—121	122	123	124—				
-125	126	128—129	130—131	132	133	134	135	136—137	138	139	140	141—142	143	144	145				
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415b	417	418	419a	419b	420	421a	421b	422a	422b	423	424a	424b	425a	425b	425c	426	427a	427b	428a
428b	429a	429b	430	431a	431b	432a	432b	435	436										

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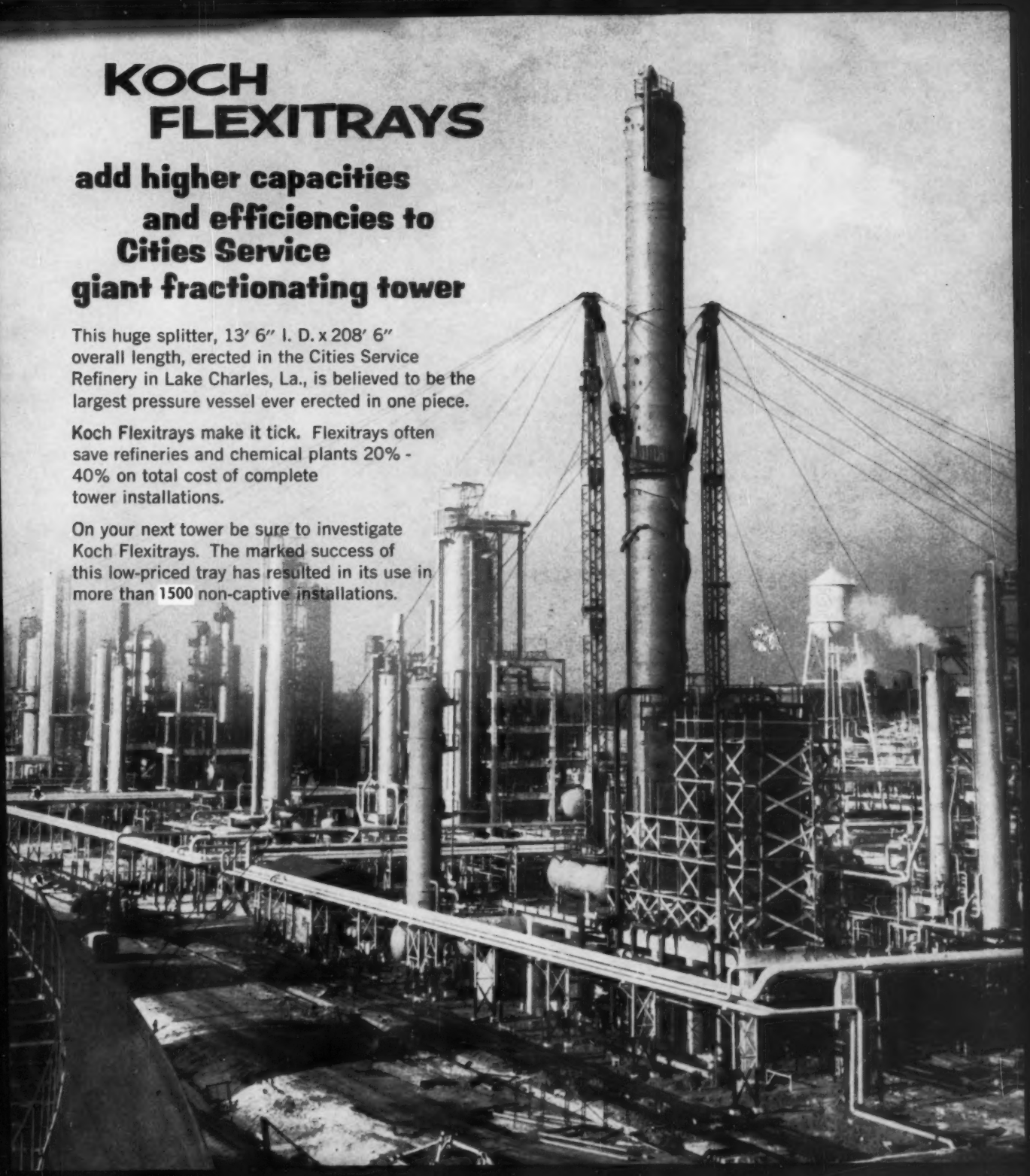
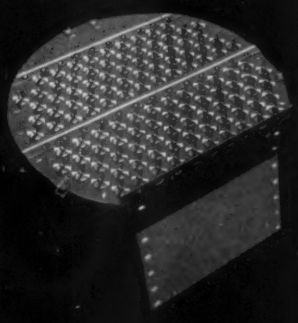
On your next tower be sure to investigate Koch Flexitrays. The marked success of this low-priced tray has resulted in its use in more than 1500 non-captive installations.





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